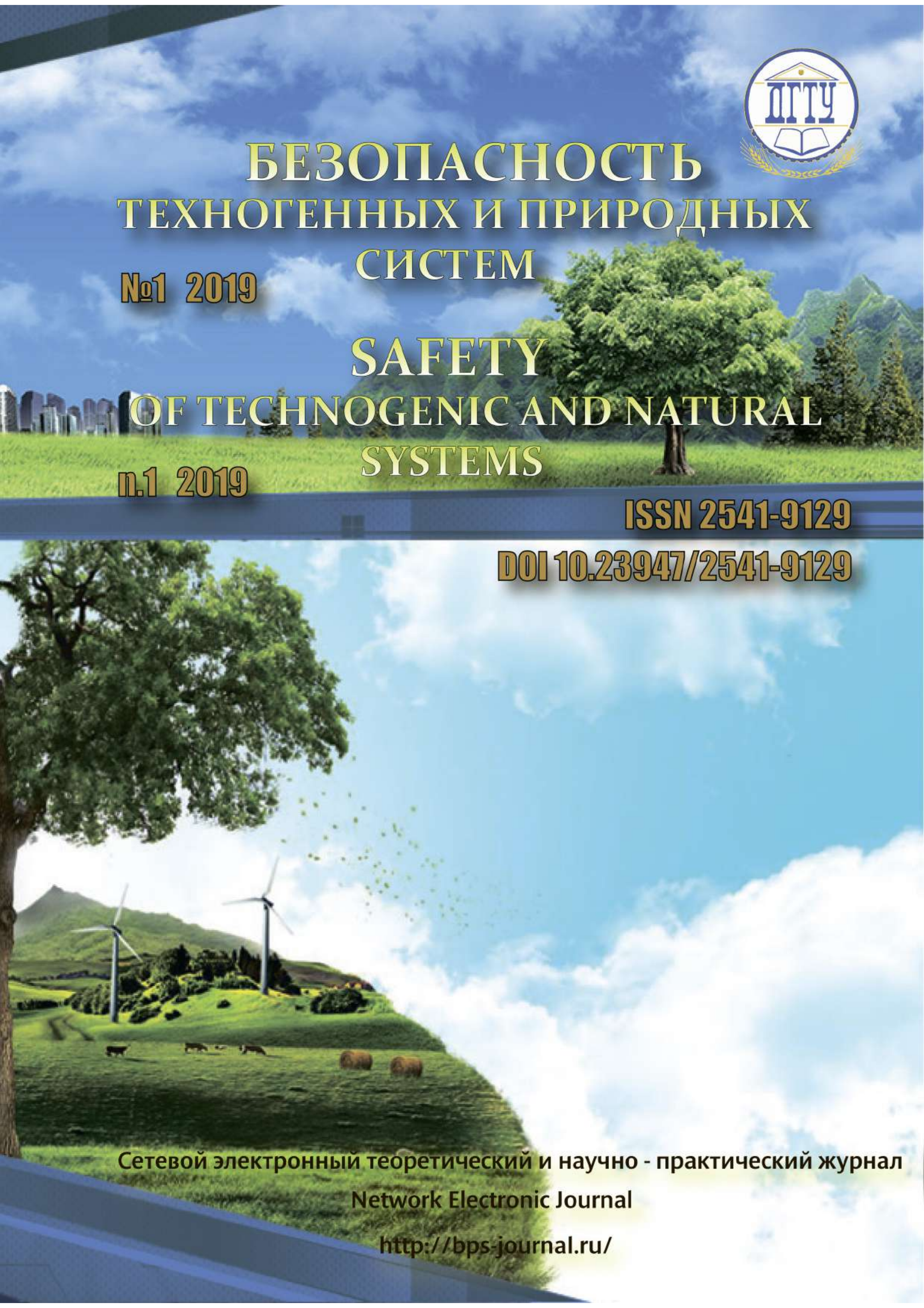

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THE VALUE OF THE ASSESSMENT OF OCCUPATIONAL RISKS IN THE SYSTEM OF OCCUPATIONAL SAFETY MANAGEMENT

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The article deals with the assessment of risks associated with safety. A study on the materials of a special assessment of working conditions (SOUT) in the processing industry. The risk factors affecting the health of workers are described.

The calculation of the risk assessment of the impact of classes of working conditions and harmful production factors in the workplace and workers according to a special assessment of working conditions. According to the results of the study and assessment of risks of labor protection revealed that the largest number of jobs and workers are affected by noise and the severity of labor, for which the risk values are among the largest and correspond to high (intolerable) risk.

Recommendations on risk management strategy are given.

Keywords: occupational safety, occupational risk, harmful factors, special assessment of working conditions.

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ЗНАЧЕНИЕ ОЦЕНКИ ПРОФЕССИОНАЛЬНЫХ РИСКОВ В СИСТЕМЕ УПРАВЛЕНИЯ ОХРАНОЙ ТРУДА

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Рассмотрены вопросы оценки рисков, связанных с безопасностью труда. Проведено исследование по материалам специальной оценки условий труда (СОУТ) на предприятии перерабатывающей промышленности. Описаны факторы риска, влияющие на состояние здоровья работников. Проведен расчет оценки рисков влияния классов условий труда и вредных производственных факторов на рабочих местах и работников по данным специальной оценки условий труда. По результатам исследования и оценки рисков охраны труда выявлено, что наибольшее количество работников подвергается влиянию факторов, соответствующих классу высокого (непереносимого) риска. Сформулированы рекомендации по стратегии управления рисками.

Ключевые слова: охрана труда, профессиональный риск, вредные факторы, специальная оценка условий труда.

Introduction. There are various methods of assessment of occupational risk from constantly operating factors of production activity, approved by the labor protection norms. They are designed to determine the degree of exposure to harmful factors on health of workers and risk category [1-2]. The occupational health and safety management system has several tools at its disposal to generate the information flows necessary to assess and make decisions on improving working conditions or the acceptability of existing residual risks. Each data collection mechanism is unique in its own way, but not universal, and each has its own drawbacks. Therefore, in these conditions, an integrated approach is needed that would improve the system of assessment of safety and comfort of work. One of the tools (with some limitations) may be occupational risks calculation [3-6].

Problem statement. Basically, occupational risk assessment is carried out only on occupational diseases indicator, which leads to incorrect results. There are good reasons to believe that the official statistics of the identified occupational diseases in Russia do not reflect the real situation, which means that only a small part of the diseases resulting from the impact of production factors is diagnosed and recorded [2, 7-8].

Theoretical part. Risk assessment is usually carried out in accordance with the following stages: hazard identification, exposure assessment, dose — response assessment, risk characterization. Initial data for carrying out occupational risk assessment calculations are results of:

- production control carried out in accordance with SP 1.1.1058-01;
- state sanitary and epidemiological supervision;
- sanitary and epidemiological assessment of production equipment and products for production purposes;
- special assessment of working conditions carried out in accordance with Federal law No. 426-FZ of 28.12.2013.;
- periodic medical examinations of employees carried out in accordance with article 213 of the Labor code of the Russian Federation [9-12].

In the framework of this study, the working conditions at LLC "Mariinsky Distillery" were considered. The work is based on the results of special assessment of working conditions (SAWC) [1-3, 13]. The company has 194 workplaces, which involve 219 people. 32.4% of employees work in hazardous working conditions (working conditions classification (KUT) 3.1 and 3.2).

According to the method [5] we carry out risk calculations.

Calculation of the risk of KUT impact in the workplace

Given:

$N_{общ}$ = 20 workplaces;

$N_{кут\ 2.0}$ = 3 workplaces;

$N_{кут\ 3.1}$ = 0 workplaces;

$N_{кут\ 3.2}$ = 17 workplaces.

Result of calculation:

1. Calculation of SAWC weighting factor on KUT, $К_{вкут i}$:

$$К_{вкут i} = \frac{N_{кут i}}{N_{общ}}, \tag{1}$$

$$K_{в\ 2.0} = 3/20 = 0{,}15,$$

$$K_{в\ 3.1} = 0/20 = 0,$$

$$K_{в\ 3.2} = 17/20 = 0{,}85;$$

2. Calculation of the weighted average values of KUT risk impact, $\overline{Rкут}$:

$$\overline{Rкут} = \sum_{i=1}^{n} К_{вкут i} \times X_{кут i}, \tag{2}$$

$$\overline{Rкут} = 0{,}15 * 2 + 0{,}85 * 4 = 3{,}7;$$

3. Calculation of the additional value of excess of the weighted average value of KUT risk impact, $\overline{\Delta R_{кут}}$:

$$\overline{\Delta R_{кут}} = \frac{\overline{R_{кутпрев}}}{\bar{R}кут}, \tag{3}$$

$$\overline{R_{кутпрев}} = \sum_{i=1}^{n} K_{вкутпрев i} \times X_{кутпрев i}, \tag{4}$$

$$\overline{R_{кутпрев}} = 0{,}85 * 4 = 3{,}4.$$

$$\overline{\Delta R_{кут}} = 3{,}4 / 3{,}7 = 0{,}92;$$

4. Calculation of the total value of the labor safety risk SAWC on KUT:

$$R_{кут} = \overline{R_{кут}} + \overline{\Delta R_{кут}}, \tag{5}$$

$R_{кут}$ = 3,7+ 0,92 = 4,62 (High (intolerable) risk).

Calculation of the risk of influence of workplace hazards in the wine shop.

Table 1

Initial data for calculation of SAWC occupational safety risks on the types of workplace hazards at workplaces

Workplace hazards	Working conditions classification			Total
	1 and 2	3.1	3.2	
Noise	3	-	17	20
Chemical	7	-	-	7
Srongly fibrogenic aerosols	-	-	-	-
Vibration	-	-	-	-
Non-ionizing radiation	3	-	-	3
Microclimate parameters	14	-	-	14
Light environment parameters	14	-	-	14
Severity of work process	3	14	-	17
Intensity of work process	-	-	-	-

Calculation of weighting coefficient of the influence of noise in the workplace, $К_{вовпф j}$:

$$К_{в\ шум\ 2.0} = 3/20=0,15,$$

$$К_{в\ шум\ 3.2} = 17/20=0,85.$$

The weighted average calculation of the risk value of the noise effect, $\overline{R_{шум}}$:

$$\overline{R_{шум}} = 0,65 * 2 + 0,28 * 3 + 0,07 * 4 = 2,42 = 0,15*2+0,85*4=3,7.$$

Additional value of excess of average risk value of noise effect at the workplace, $\overline{\Delta R_{шум}}$:

$$\overline{R_{превшум}} = 0,28 * 3 + 0,07 * 4 = 1,12 = 0,85*4=3,4,$$

$$\overline{\Delta R_{шум}} = \frac{1,12}{2,42} = 0,46 = 3,4/3,7 = 0,92.$$

The total value of risk of influence of the noise factor in the workplace:

$\overline{R_{шум}}$ = 3,4 + 0,92 = 4,32 – high (intolerable) risk.

Let us calculate risk value of chemical factor influence in the workplace:

$$К_{в\ хим\ 2.0} = 7\ /\ 7= 1,$$

$$\overline{R_{хим}} = 0,95 * 2 + 0,05 * 3 = 2,05 = 1* 2=2.$$

Total risk value of chemical factor influence in the workplace:

$\overline{R_{хим}}$ = 2 (negligible, tolerable risk).

Risk value of non-ionizing radiation in the workplace:

$$К_{в\ н.и\ \ 2.0} = 3\ /\ 3= 1,$$

$$\overline{R_{неии}}= 1* 2=2,$$

$\overline{R_{неии}}$= 2 (negligible, tolerable risk).

Risk value of microclimate factor influence in the workplace:

$$К_{в\ мк\ 2.0} = 14/14=1,$$

$$\overline{R_{мк}} = 1 * 2 = 2,$$

$R_{мк} = 2$ (negligible, tolerable risk).

Risk value of light environment influence in the workplace:

$$К_{в\ свет\ 2.0} = 14/14 = 1,$$

$$\overline{R_{свет}} = 1 * 2 = 2,$$

$R_{свет} = 2$ (negligible, tolerable risk).

Risk value of the severity of labor process influence in the workplace:

$$K_{\textit{в тяж 2.0}} = 3/17 = 0{,}18,$$

$$K_{\textit{в тяж 3.1}} = 14/17 = 0{,}82,$$

$$\overline{R_{\text{тяж}}} = 0{,}18 * 2 + 0{,}82 * 3 = 2{,}82,$$

$$\overline{R_{\text{превтяж}}} = 0{,}82 * 3 = 2{,}46,$$

$$\overline{\Delta R_{\text{тяж}}} = 2{,}46/\ 2{,}82 = 0{,}87,$$

$$R_{\textit{тяж}} = 0{,}87 + 2{,}82 = 3{,}69 \text{ — average (significant) risk.}$$

After calculating the occupational safety risks according to SAWC by types of hazardous and harmful production factors in the workplace, it can be concluded that the total value of occupational safety risks by classes of working conditions is 4.62 (high intolerable risk).

The calculated values of risks according to SAWC in the wine shop are shown in the diagram (Fig. 1).

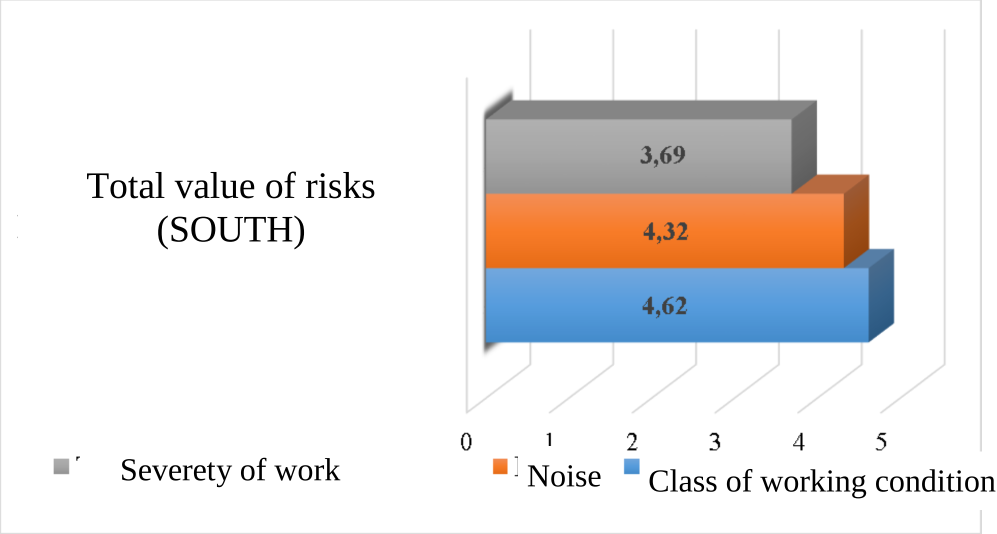

Fig.1 SAWC risk values for the wine shop

Based on the data obtained, it can be concluded that 85 % (17 out of 20) of the employees of the wine shop are exposed to high (intolerable) risk.

Conclusion. By analyzing risk assessment calculations, it can be concluded that the greatest number of employees is affected by noise and the severity of labor (noise — 4.32, the severity of labor — 3.69). The total values of risks (SAWC) for the classes of working conditions — 4.62, which corresponds to a high (intolerable) risk. These data will allow employees and directly the manager (master, shop foreman, etc.) to more often monitor the compliance with labor protection and safety rules in the shop, as well as to carry out measures to prevent professional hearing loss. This will improve working conditions in the wine shop, as well as it will have positive impact on the health and efficiency of workers. When developing recommendations for workplace health and safety risk management, a risk management strategy is needed to reduce risk by developing measures to reduce the impact of noise and the severity of the work process.

The research has revealed the fact that 85% of employees of the wine shop are exposed to the increased risk of noise in the workplace, which is the basis for a more detailed study of the impact of noise on the body and health of workers in order to predict the occurrence of occupational diseases when exposed to noise [14-15].

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IMPROVING LIFT SAFETY BY USING DIGITAL TECHNOLOGIES

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The paper deals with the organization of the dispatching of elevators, as one of the important conditions for ensuring security, and monitoring the technical condition of elevator facilities through the use of digital technologies. This method allows to increase the safety of the operation of elevators, to ensure the operational control of the state of the elevator structures both by the operating organization and by the regulatory authorities, and to reduce the negative impact on the safety of the human factor.

Keywords: elevator, accident rate, safety, human factor, information technology

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ПОВЫШЕНИЕ БЕЗОПАСНОСТИ ЛИФТОВ ПУТЕМ ПРИМЕНЕНИЯ ЦИФРОВЫХ ТЕХНОЛОГИЙ

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Рассматриваются вопросы организации применения цифровых технологий для диспетчеризации лифтов, как одного из важных условий обеспечения безопасности и контроля за техническим состоянием лифтовых сооружений. Данный способ позволяет повысить безопасность эксплуатации лифтов, обеспечить оперативный контроль состояния лифтовых сооружений эксплуатирующей организацией и контролирующими органами, снизить негативное влияние на безопасность человеческого фактора.

Ключевые слова: лифт, аварийность, безопасность, человеческий фактор, информационные технологии.

Introduction. An important infrastructure element of any medium-sized and big city is lift facility. It is on the border of housing and communal services and the construction industry. Currently, lift facilities have become a separate industry operating on a global scale and include manufacturers of elevators and related equipment, organizations providing service maintenance and operation of elevators, system integrators.

Implementation of a range of measures is required for safe operation of lift equipment: creation of a system of regulation of commissioning and accounting of elevators, assessment of their technical condition at all stages of operation; providing information and automation of control and supervisory activities through the introduction of dispatching systems; use of control and supervisory activities of risk-oriented approach taking into account human factor risk [1-4].

Dispatching of elevator equipment. Main tasks of dispatching systems of elevator equipment are to lower operating costs and to provide safety of its operation through online monitoring of equipment operation, to create database on the operation of lifts and information analysis, to provide elevator control, automatic information about errors, faults and accidents [5].

Transfer of elevators parameters is through the dedicated line of dispatching communication, through a radio channel or with the use of infrastructure of other networks (telephone or TCP/IP). The main requirement for communication lines — reliable operation, interference resistance, protection from break-ins and damage.

The dispatching system is one of the necessary conditions that ensures the safe operation of elevators, as it allows increasing the efficiency and quality of their maintenance.

Digital technologies in dispatching. One of the ways to improve operation safety of elevator facilities in general, as well as to reduce the negative impact of human factor in particular, is the development of information and communication technology — a program using mobile devices (smartphone) based on ios and android and wireless Internet, which allows:

- to increase staff performance efficiency of official and production functions;
- to monitor elevator equipment current condition;
- to ensure information transparency on the state of the object to regulating authorities;
- to ensure the timeliness of technical inspection of elevators.

There are similar developments for such lifting structures as tower cranes [6]. However, the combination of elevator equipment with mobile devices for information transmission, object inspection and remote control of Rostekhnadzor (Federal Environmental, Industrial and Nuclear Supervision Service of Russia) at all sites online was not used at such hazardous facilities as elevators. This is the main difference of the proposed technology from the existing elevator dispatching systems.

When using information and communication technologies with the use of Internet resources, all information on the state of the facility will be open to Rostekhnadzor and it will be easier to control the hazardous facility.

The principle of the program is as follows (Fig. 1): central server receives data on lift park (within the operating organization — payroll, on a larger scale — from the databases of the Unified lift information-analytical system [7]), regulatory instruments (laws, regulations, technical regulations, etc.), manuals (instructions) for operation of elevators, officials and company specifications for employees, as well as data from dispatch systems of elevators.

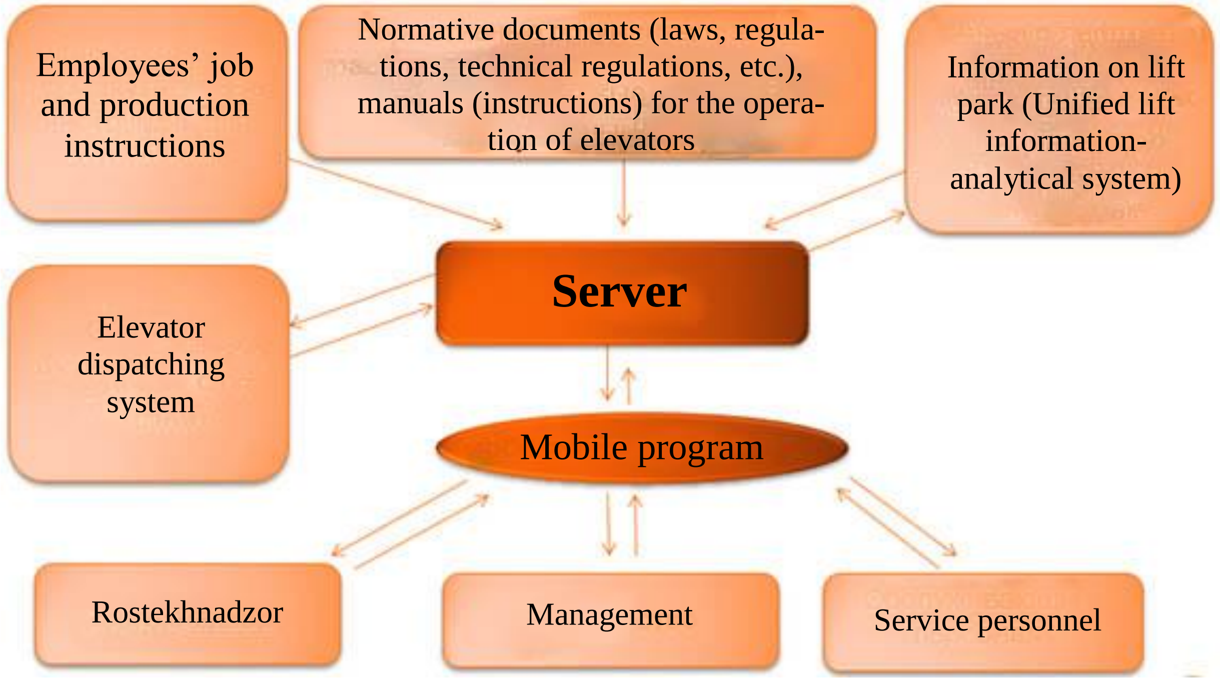
Employees' job and production instructions
Normative documents (laws, regulations, technical regulations, etc.), manuals (instructions) for the operation of elevators
Information on lift park (Unified lift information-analytical system)
Server
Elevator dispatching system
Mobile program
Rostekhnadzor
Management
Service personnel

Fig. 1. Mobile program principle

Through the mobile application, and in accordance with his position and his authority, an employee receives information on elevators condition; the necessity in any works of their maintenance, repair; the timing and execution activities for inspection, maintenance, and examination of elevators; the nomenclature and content of the regulations and instructions for operation of elevators. In addition, it is possible to complete the supporting documentation and send it to the appropriate service or authority.

The personnel will log in using their personal login and password. When you enter data, the program sends information to the employee only in accordance with his job responsibilities. Each employee will be able to receive data only personally. There will also be an opportunity to use a mobile phone as an electronic pass to the objects with NFC-technology on the phone by integrating electronic pass cards.

Registration in the system is carried out by the person responsible for the facility safe operation.

Conclusion. The development of mobile technologies imposes new requirements and provides opportunities for the creation of operational control of technical systems online. The elevator industry should not be an exception in these circumstances.

The proposed development will allow for operational control over the technical condition of the elevator industry, thereby increasing safety of their operation.

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STUDY ON PHYSICAL FEATURES OF DUST CONTROL PROCESS AT WOODWORKING ENTERPRISE

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The article is devoted to the analysis of physical essence of the process of air pollution reduction for the woodworking shop of the enterprise serving the objects of urban development, within the framework of physical and energy approach. According to this approach, wood dust is considered from the position of disperse systems theory, which changes its properties under the influence of external disperse systems. The whole process is gradually illustrated by a physical model of air pollution reduction process, as well as a scheme of transformation of the disperse system (dust aerosol) in the process of air pollution reduction.

Keywords: environmental safety in construction, object of urban development, disperse system, woodworking shop, wood dust, air pollution reduction, physical energy approach, physical model of air pollution reduction process.

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ИССЛЕДОВАНИЕ ФИЗИЧЕСКИХ ОСОБЕННОСТЕЙ ПРОЦЕССА ПЫЛЕПОДАВЛЕНИЯ НА ДЕРЕВООБРАБАТЫВАЮЩИХ ПРЕДПРИЯТИЯХ

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Статья посвящена анализу физической сущности процесса снижения загрязнения воздушной среды для деревообрабатывающего цеха предприятия, обслуживающего объекты городского строительства, в рамках физико-энергетического подхода. Согласно этому подходу древесная пыль рассматривается с позиции теории дисперсных систем, которая меняет свои свойства под воздействием внешних дисперсных систем. Весь процесс поэтапно иллюстрирует физическая модель процесса снижения загрязнения воздушной среды, а также схема трансформации дисперсной системы (пылевого аэрозоля) в процессе снижения загрязнения воздушной среды.

Ключевые слова: экологическая безопасность в строительстве, объект городского строительства, дисперсная система, деревообрабатывающий цех, древесная пыль, снижение загрязнения воздушной среды, физико-энергетический подход, физическая модель процесса снижения загрязнения воздушной среды.

Introduction. Promising development of the Russian construction industry using wood products such as shuttering, frame houses elements, joists and floorboards, plywood, parquet products inevitably leads to aggravation of air pollution problems with wood dust in the processing of wood raw materials [1, 2]. Therefore, the modern level of production development involves the use of scientifically based approaches to the choice of methods and means of ensuring environmental safety in construction that meet the requirements of environmental and energy efficiency [3, 4]. At the same time, physical-energy approach is the most preferable for the above criteria for solving such problems [5].

Main part. According to this approach, dust, formed as a result of woodworking, is considered according to the theory of disperse systems [6-8]. The properties of wood dust particles as a dispersed phase suspended in air or gas flow may differ significantly from the properties of the captured dust material [9]. This difference may occur especially in the removal of wood dust from the air. This happens due to the fact that a certain proportion of wood dust particles in the ventilation air flow is an aggregate consisting of several dust particles. Such aggregates behave like large particles. The more dust aggregates in the air, the easier it is to separate them from the flow and thus ensure a sufficiently high cleaning efficiency [10].

For wood dust, an effective reduction of air pollution of the construction company working area and the atmosphere surface layer is achieved by the implementation of two main cycles [5]:

– reduction of pollution of wood raw materials or technological equipment;

– reduction of air pollution by wood dust.

It is obvious that the first cycle (consolidation and retention of wood dust particles) is more rational, but its implementation does not ensure compliance with the MPC in the working area air and in the atmosphere surface layer [12].

The second cycle (capture, cleaning, dispersion) is traditionally used to comply with the regulatory parameters of air environment in the construction industry. The second cycle of the process of reducing air pollution with wood dust includes the appropriate stages of implementation.

To investigate physical nature of air pollution reduction process with wood dust, we present this process as a set of consistently occurring targeted processes implemented at each stage of pollution in the process of woodworking at the construction industry.

The first cycle consists of the following functional elements:

– dust consolidation, which is strong consolidation of dust material particles with wood raw material;

– dust retention, namely, to retain the formed particles of wood dust in the vicinity of wood raw material.

The second cycle includes:

– dust capture, which is to prevent the spread of wood dust particles and ensure their removal from air directly in the area of its source;

– dust cleaning, consisting in the maximum separation of the dispersed phase and the dispersion medium of dust;

– dust dispersion, namely, the intensive separation of wood dust particles in air medium with subsequent settling.

Dispersion of wood dust particles in the atmosphere can occur naturally or by force. Natural dispersion involves the release of wood dust at the roof level of the working area building and is largely dependent on meteorological conditions (wind speed, temperature, relative humidity, etc.) and the state of the atmosphere surface layer (potential air pollution, stratification factor, etc.). In this case, if the efficiency of the cleaning process does not meet regulatory requirements (MPE), forced dispersion is applied. The analysis of cleaning process shows the need for dispersion of wood dust particles.

The analysis results of the process of reducing environmental pollution with wood dust formed the basis for the construction of a physical model of this process for the enterprise woodworking shop serving the objects of urban construction (Fig. 1).

In the process of interaction of raw materials (dry edged board) with the working body of technological equipment (cutting head blade of four cutter) wood dust is formed, which is an "Initial-I"("И–I") disperse system.

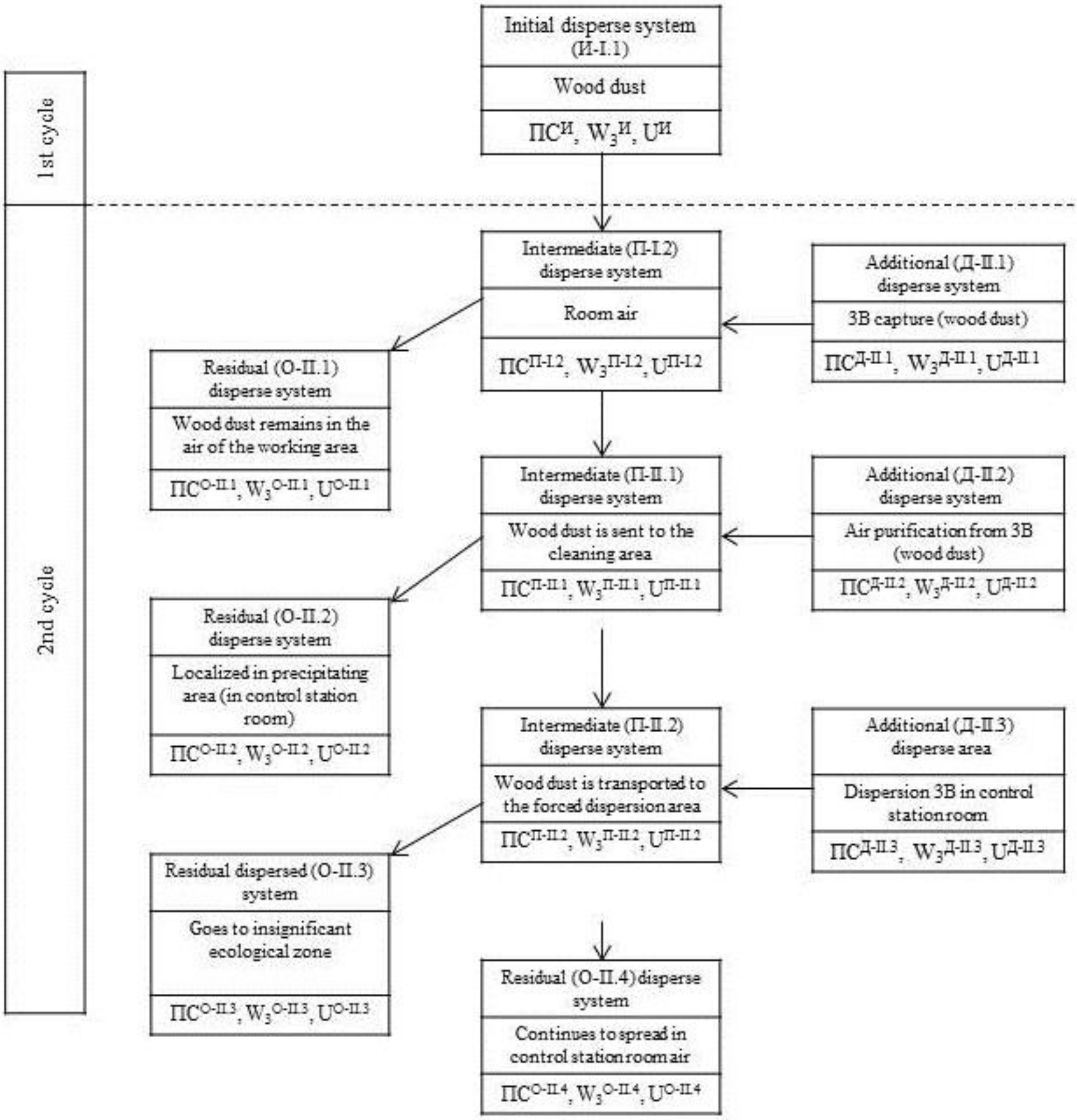
1st cycle
2nd cycle
Initial disperse system (И-I.1)
Wood dust
$ПС^{И}, W_3^{И}, U^{И}$
Intermediate (П-I.2) disperse system
Room air
$ПС^{П-I.2}, W_3^{П-I.2}, U^{П-I.2}$
Additional (Д-II.1) disperse system
3B capture (wood dust)
$ПС^{Д-II.1}, W_3^{Д-II.1}, U^{Д-II.1}$
Residual (O-II.1) disperse system
Wood dust remains in the air of the working area
$ПС^{O-II.1}, W_3^{O-II.1}, U^{O-II.1}$
Intermediate (П-II.1) disperse system
Wood dust is sent to the cleaning area
$ПС^{П-II.1}, W_3^{П-II.1}, U^{П-II.1}$
Additional (Д-II.2) disperse system
Air purification from 3B (wood dust)
$ПС^{Д-II.2}, W_3^{Д-II.2}, U^{Д-II.2}$
Residual (O-II.2) disperse system
Localized in precipitating area (in control station room)
$ПС^{O-II.2}, W_3^{O-II.2}, U^{O-II.2}$
Intermediate (П-II.2) disperse system
Wood dust is transported to the forced dispersion area
$ПС^{П-II.2}, W_3^{П-II.2}, U^{П-II.2}$
Additional (Д-II.3) disperse area
Dispersion 3B in control station room
$ПС^{Д-II.3}, W_3^{Д-II.3}, U^{Д-II.3}$
Residual dispersed (O-II.3) system
Goes to insignificant ecological zone
$ПС^{O-II.3}, W_3^{O-II.3}, U^{O-II.3}$
Residual (O-II.4) disperse system
Continues to spread in control station room air
$ПС^{O-II.4}, W_3^{O-II.4}, U^{O-II.4}$

Fig. 1. Physical model of the process of reduction of air environment pollution for woodworking shop

In this case external influence on "И-I" system in the capture process is an additional disperse system "Д-II.1". Two disperse systems are formed as a result of the interaction of "И-I" and "Д-II.1." disperse systems:

– "O-II.1" system, which is initially in a state of wood dust, but loses its stability. It can go into the initial material state, but in the real world remains in the air of the working area;

– "П-II.1" disperse system contains the maximum amount of dispersed phase. The stability of the system increases slightly over time. The system moves to the cleaning area.

"Д-II.2" system has an impact on "П–II.1" in the purification process. In this case, two systems are formed:

– "O-II.2" - fixed disperse system directed to the waste system. It is characterized by a high content of dust particles and increased stability.

– "П-II.2" - a polluting dust with a certain residual concentration of wood dust particles directed either to the atmosphere (in compliance with the MPE) or to the zone of forced dispersion.

Two systems are also formed in the process of forced dispersion (when this happens "П-II.2" and "Д-II.3" disperse systems interact):

– "О-II.3" - is directed to ecologically insignificant areas in the form of aerosol. The stability of the system first falls, then it stabilizes.

– "О-II.4 " - continues to spread in the air of the atmosphere surface layer. It is represented by a minimum number of wood dust particles, remains in aerosol state; its stability grows slightly in time, then it stabilizes.

As a result of successive influence on the initial, intermediate and residual disperse systems by external disperse systems in accordance with the laws of conservation of mass and energy, there is a transformation of interacting disperse systems. This transformation means that the newly formed disperse systems differ from the interacting ones in ПС, W, U. This inter-transition of disperse systems ultimately affects their stability and can be illustrated by the following scheme. Fig. 2 provides an illustration of transformation of disperse dust aerosol systems and changes in their stability in the process of air pollution reduction.

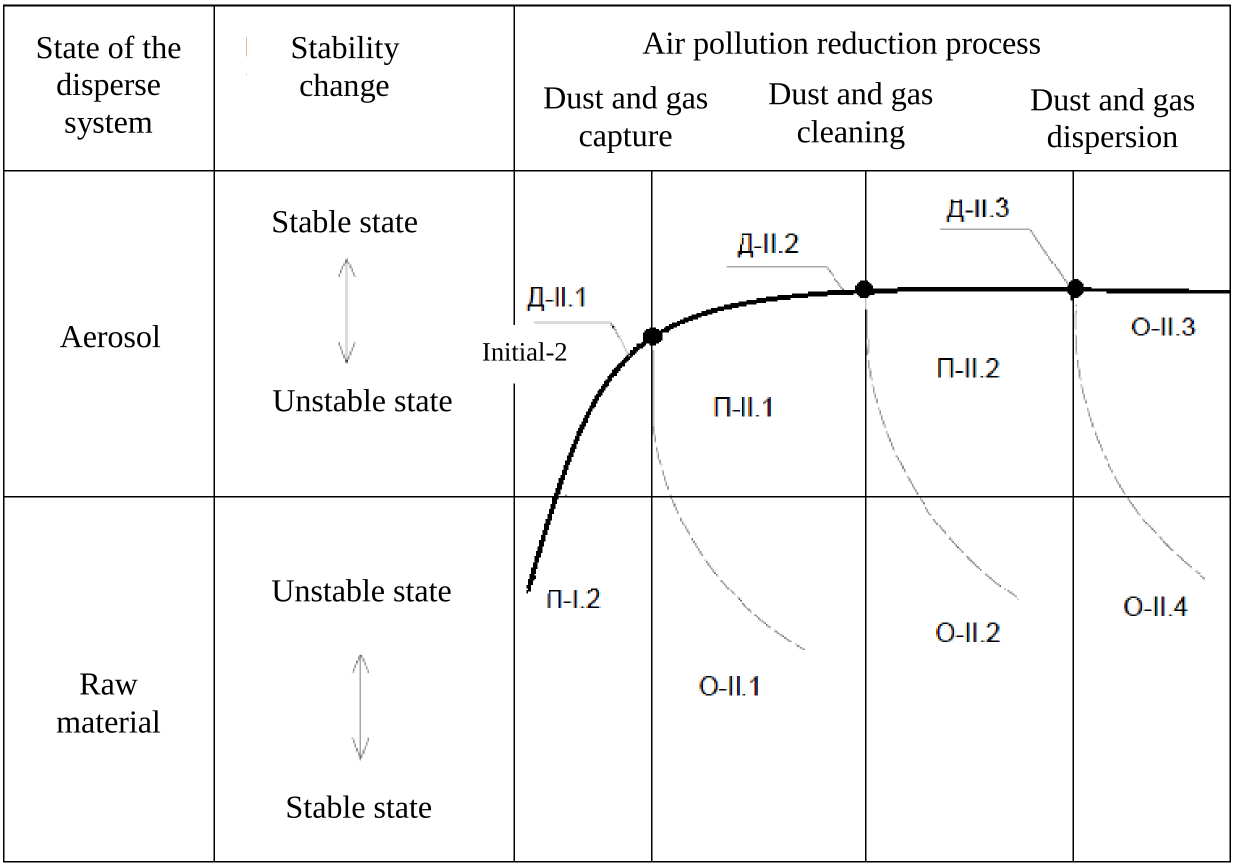

Fig. 2. Scheme of transformation of the wood dust disperse system in the process of air pollution reduction

Conclusion. The analysis of physical nature of air pollution reduction process for the woodworking shop will allow further research to move to the stage of selection of environmentally and energy efficient methods and means of ensuring environmental safety in construction, taking into account the transformations of the polluting disperse system, which "additional" disperse systems subject it to at the stages of capture, purification and dispersion of wood dust.

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INTEGRATED METHOD OF OCCUPATIONAL RISK DEGREE ASSESSMENT AT THE ENTERPRISE

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The authors have developed an integrated method for occupational risk assessment at the enterprise, taking into account statistical data from 2008 to 2017. The analysis of occupational accidents has shown that occupational risk assessment should consider competence of workers, working conditions, accidents at production, not connected with the human factor. Matrix of harm and the severity of that harm is calculated for each accident factor. The essence of the method is that for each situation the specialist determines the rank of probability of its occurrence and the potential damage corresponding to this situation. According to this practice, risk can have three meanings: "unacceptable", "high" and "acceptable". The value of risk is determined as the intersection of the categories of employee competence, working conditions, accidents at work, not related to the human factor. Thus, an occupational risks assessment and management system is developed aimed at preserving life and health of employees, taking into account statistical data on accidents from 2008 to 2017. The results of the study allow us to conclude that the high level of competence of the employee in the field of labor protection can significantly reduce occupational injuries, despite the harmful working conditions and the high risk of an accident at work, which is not associated with the human factor.

Keywords: the complex method of assessment, professional risk, working environment.

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КОМПЛЕКСНЫЙ МЕТОД ОЦЕНКИ СТЕПЕНИ ПРОФЕССИОНАЛЬНЫХ РИСКОВ НА ПРЕДПРИЯТИИ

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Разработан комплексный метод оценки профессиональных рисков на предприятии с учетом статистических данных за период с 2008 по 2017 г. Анализ производственного травматизма показал, что при оценке профессиональных рисков следует учитывать компетентность работника, условия труда, аварийность на производстве, не связанную с человеческим фактором. Для каждой предпосылки к несчастному случаю рассчитаны матрицы ущерба и тяжести этого ущерба. Сущность метода заключается в том, что специалист для каждой ситуации определяет ранг вероятности ее наступления и соответствующий этой ситуации потенциальный ущерб. В соответствии с данной методикой риск может принимать три значения: «неприемлемый», «высокий» и «приемлемый». Значение риска определяется как пересечение категорий компетентности работника, условий труда, аварийности на производстве, не связанной с человеческим фактором. Таким образом, создана система оценки и управления профессиональными рисками, направленная на сохранение жизни и здоровья работников, с учетом статистических данных по несчастным случаям с 2008 по 2017 год. Результаты исследования позволяют сделать вывод о том, что высокий уровень компетентности работника в области охраны труда позволяет значительно снизить производственный травматизм, несмотря на вредные условия труда и высокий риск аварии на производстве, который не связан с человеческим фактором.

Ключевые слова: комплексный метод оценки, профессиональный риск, условия труда.

Introduction. In accordance with the regulatory and legal occupational safety documentation, since 2013 all enterprises of Russia have been assessing "occupational risk". "Occupational risk" is the probability of an accident (occupational disease) of an employee in the performance of duties under the employment contract. Risk is the probability of causing harm to health of an employee, the possibility of undesirable consequences, the measure of possible danger and the consequences of its realization (damage). The term "occupational risk" is used for the first time in the ILO recommendations "On health services in the enterprise" (1959).

According to GOST R 51898-02 risk is defined as the product of the probability of damage and the severity of the consequences of this damage:

$$R=P\cdot U. \tag{1}$$

In accordance with the occupational safety legal acts, the head of the enterprise is obliged to calculate the occupational risks for the staff.

Occupational risk is determined in order to establish the degree of danger of buildings, structures, equipment and technologies, to assess the state of occupational safety and to develop a system of preventive measures (organizational, technical) to reduce the level of occupational injuries. The author has developed a method for occupational risks assessment at the enterprise, taking into account statistical data from 2008 to 2017. The analysis of occupational injuries at enterprises from 2008 to 2017 showed that the most common types of accidents (A) are: impact of moving parts (29 %), deterioration of employee' health (21 %), accident (19 %), fall from a height (13 %).

Based on statistical data, the main reasons leading to the accidents were identified: non-compliance with occupational safety requirements — 57 %; deterioration of health of a worker (which is associated with harmful working conditions at the enterprise, with violations in the use of PPE and ignoring medical examinations) — 21 %; accidents at work (risk of injury taking into account products and structures used) — 22 %. According to statistics, workers between 18 and 25 years of age and over 45 years of age are the most likely to be injured. At the same time, 42% of accidents occurred in the period from 8 to 10 am. Taking into account the statistics of accidents from 2008 to 2017, it is possible to determine the main criteria for occupational risks assessment.

Main part. The analysis of occupational injuries showed that occupational risk assessment should take into account:

- competence of an employee;
- working conditions;
- accidents at work, not related to the human factor (violation of stability, breakage, unpredictable change in the internal state of potentially dangerous substances).

For a comprehensive assessment of occupational risks for each precondition for accidents or occupational disease (OD), we calculate the matrix of the occurrence probability of danger and severity of consequences.

The essence of the proposed method for determining the predicted occupational risks assessment using the materials of a special assessment of working conditions is that a labor protection service specialist for each situation determines the rank of the probability of occurrence of an accident or OD (low probability, medium probability, high probability) and the potential damage corresponding to this situation (small, medium, great).

To assess the degree of compliance of SAWC with the regulatory requirements and the degree of influence on the human body of harmful and dangerous factors of working conditions, we use a system of special points:

1 — optimal working conditions (class 1);
4 — permissible working conditions (class 2);
8 — not quite favourable working conditions (class 3.1);
12 — adverse working conditions (class 3.2));
15 — very poor working conditions (class 3.3);
20 — extreme, critical working conditions (class 3.4).

The higher the score, the greater the dangerous and harmful effects on the human body (non-compliance of working conditions with regulatory requirements). The results of a special assessment of working conditions are used to assess the negative impact of the working environment. The class of working conditions is determined in accordance with the Federal law No. 426 of December 28, 2013. The score corresponds to the degree value of the conditions status *R1*.

The work does not take into account manager competence, because the result of his organizational work directly affects personnel training.

According to GOST 12.0.230-2007, "competent person is a person with the necessary training and sufficient knowledge, skills and abilities to perform a specific job".

Table 1

Levels of probability of accident occurrence at different competence levels of an employee

Probability level	Probability	Number of accidents
1	Very low, 10^{-4}	0–2 for the whole period of research
2	Low, $5\cdot10^{-4}$	Once in 5 years
3	Medium, $2{,}7\cdot10^{-3}$	Once a year
4	High, $5{,}4\cdot10^{-3}$	Twice a year
5	Very high, $3\cdot10^{-2}$	Once a month

Table 2

Degree of consequences severity at different competence levels of an employee

Severity of consequences	Damage	Condition of the employee
1	Very low	pain without consequences for health
2	Low	deterioration of health with treatment in the emergency room (absence at work 3 days)
3	Medium	accident with mild health damage (absence at work less than 30 days)
4	High	accident with severe health damage (absence at work for more than 30 days)
5	Very high	fatal accident

The conditional value of risk is determined at the intersection of the corresponding column and row. In this case, the amount of risk can be represented in quantitative terms. Matrix values are chosen in accordance with statistical data on accidents in the workplace.

Table 3

Degree of risk R2 due to the incompetence of an employee

	Probability level					
Degree of harm	1	2	3	4	5	6
	2	1	2	3	4	5
	3	2	4	6	8	10
	4	3	6	9	12	15
	5	4	8	12	16	20
	6	5	10	15	20	25

Competence levels can be defined as follows:

- competent (risk level 1-5) - the employee is able to perform work independently in compliance with the occupational safety requirements;

- incompetent (risk 6-10) — the employee has some competencies, poor talent to perform his work in compliance with the occupational safety requirements. The employee requires control. Incompetent employees include employees who do not have practical experience with particularly dangerous works, regardless of the level of theoretical knowledge of the occupational safety requirements, as there is no skills of safe performance of works. These employees need training;

- incompetent (risk level 12-24) — the employee is not able to independently perform work in compliance with the occupational safety requirements; unconsciously violates the occupational safety requirements. The employee is not allowed to work. Additional training is required for the worker to comply with safety measures in the workplace. It is necessary to work out first aid practical actions of personnel, evacuation in case of an accident, methods of accident localization;

- dangerously incompetent — the employee is not able to independently identify, assess and manage risks in the performance of work; deliberately violates the occupational safety requirements, regulating work that is associated with high risk. Dangerously incompetent worker is not allowed to work.

In assessing competence safety engineer must take into account:

- possible risks of violations of the occupational safety requirements due to insufficient knowledge, skills, abilities;

- actual risks caused by: violations of the requirements of industrial and occupational safety; intentional violations of safety requirements, which are associated with negligence, irresponsibility of an employee and non-observance of labor discipline; work experience.

All the above-mentioned possible and actual risks (preconditions of emergency or accident) should be taken into account to assess the competence of an employee. This will give full information about the readiness of personnel to perform work in the workplace.

Calculation of accident rate at the production (stability violations, breakdowns, unpredictable changes in the internal state of potentially hazardous substances) is carried out taking into account the characteristics of structures, time and operating conditions.

Table 4

Levels of probability of an accident at work for reasons that do not depend on an employee

Probability level	Probability	Number of accidents
1	Very low, 10^{-4}	0–2 for the whole period of research
2	Low, $5\cdot10^{-4}$	Once in 5 years
3	Medium, $2{,}7\cdot10^{-3}$	Once a year
4	High, $5{,}4\cdot10^{-3}$	Twice a year
5	Very high, $3\cdot10^{-2}$	Once a month

Table 5

Severity of accident consequences in production for reasons that do not depend on an employee

Severity of consequences	Damage	Condition of the employee
1	Very low	pain without consequences for health
2	Low	deterioration of health with treatment in the emergency room (absence at work 3 days)
3	Medium	accident with mild health damage (absence at work less than 30 days)
4	High	accident with severe health damage (absence at work for more than 30 days)
5	Very high	fatal accident

Table 6

R3 risk level due to the production environment

	Probability level					
Degree of harm	1	2	3	4	5	6
	2	1	2	3	4	5
	3	2	4	6	8	10
	4	3	6	9	12	15
	5	4	8	12	16	20
	6	5	10	15	20	25

The values of the matrix are selected according to the statistical data of industrial accidents.

Risk assessment:

1. from 1 to 5 (low). The low degree of risks indicates the effective work of the company's management in the field of occupational safety;

2. from 6 to 10 (average). With the degree of risk from 6 to 10 a plan of measures should be developed to eliminate and minimize risks, indicating the timing of elimination of deficiencies and responsible persons;

3. from 12 to 25 — the degree of risk is high. With the degree of risks from 12 to 25, measures to reduce risks are taken slowly;

4. 25 — the risk is very high. With a degree of 25, an enterprise shutdown is required.

The author has developed the following matrix model of integrated assessment of occupational risk degree.

Table 7

Matrix of risk degree taking into account incompetent actions of personnel
and the fact of an accident at work (which is not related to the human factor)

	Риск некомпетентных действий персонала			
Risk of accident at work		Low risk	Medium risk	High risk
	Low risk	🟩	🟨	🟨
	Medium risk	🟩	🟨	🟥
	High risk	🟨	🟥	🟫

Table 8

Matrix of risk degree taking into account incompetent actions of personnel and working conditions at the enterprise

	Risk of incompetent actions of personnel			
Risk, taking into account working conditions		Low risk	Medium risk	High risk
	optimal working conditions (class 1)	🟩	🟨	🟨
	acceptable working conditions (class 2)	🟩	🟨	🟥
	not quite favorable working conditions (class 3.1)	🟩	🟨	🟥
	adverse working conditions (class 3.2)	🟨	🟨	🟥
	very poor working conditions (class 3.3)	🟨	🟥	🟥
	critical working conditions (class 3.4)	🟨	🟥	🟫

Table 9

Matrix of risk degree taking into account working conditions and the fact of an accident at work (which is not related to the human factor)

	Risk of accident at work			
Risk, taking into account working conditions		Low risk	Medium risk	High risk
	optimal working conditions (class 1)	🟩	🟩	🟨
	acceptable working conditions (class 2)	🟩	🟩	🟨
	not quite favorable working conditions (class 3.1)	🟩	🟨	🟨
	adverse working conditions (class 3.2)	🟨	🟨	🟥
	very poor working conditions (class 3.3)	🟨	🟥	🟥
	critical working conditions (class 3.4)	🟨	🟥	🟫

A graphical representation of risk degree as a whole is shown in Fig. 1.

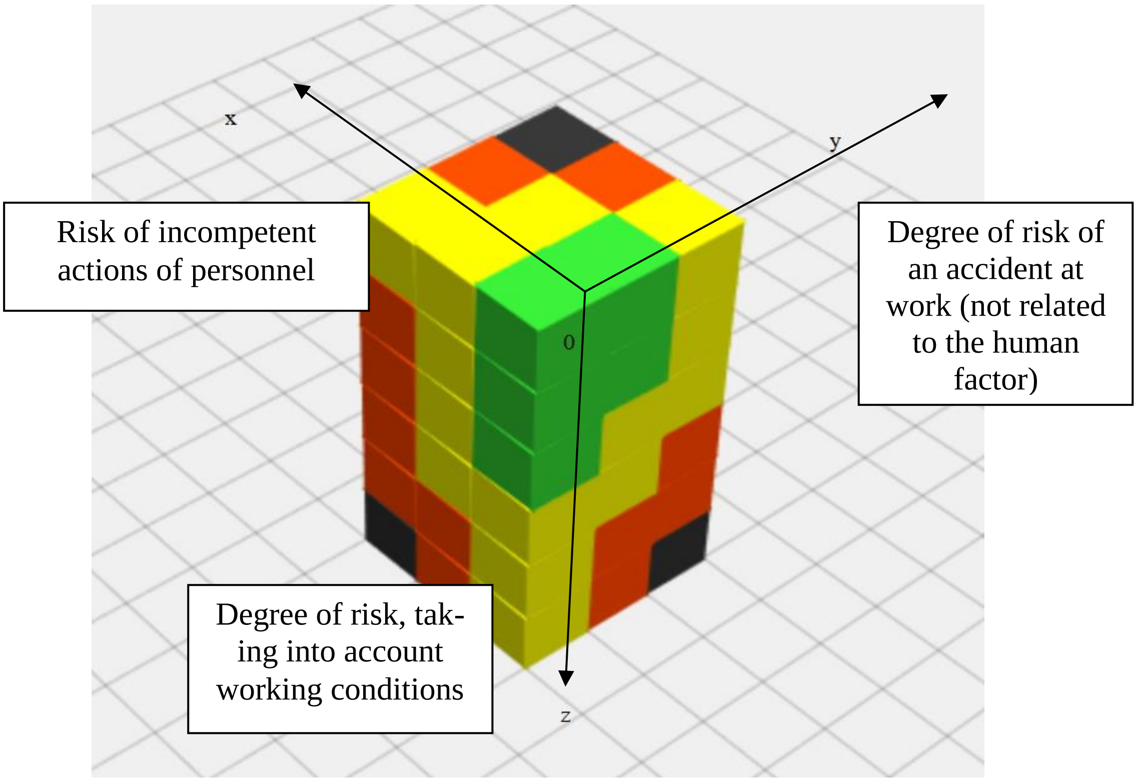
x
y
0
z
Risk of incompetent actions of personnel
Degree of risk of an accident at work (not related to the human factor)
Degree of risk, taking into account working conditions

Fig. 1. Matrix model of integrated assessment of occupational risks

In accordance with the methodology, an integrated risk assessment can take the following values: "acceptable", "medium", "high" and "dangerous".

The value of risk degree is determined as the intersection of the categories of competence of an employee, working conditions, accidents at work (not related to the human factor).

The intersection point determines the degree of risk:

- green zone, the degree of risk is "acceptable", the work can be started with compliance with the existing safety requirements;
- orange zone, the risk level is "medium", the work can be started after the written approval of the manager;
- red zone, the degree of risk is "high", urgent organizational and technical measures in the field of occupational safety are required. The work cannot be started due to the high probability of occurrence of emergencies or accidents;
- black zone, the degree of risk is "dangerous". Production must be suspended.

The engineer finds the values from the matrices shown in tables 7-9. Further, based on the values found, a decision is taken on the admission of workers to production and measures are taken to reduce accident risks.

The author has formulated an integrated assessment of risk degree caused by occupational risk taking into account working conditions, competence of the worker and accident rate at production. Further there is a statistical model of the degree of risk.

Main causes that lead to emergencies and accidents from 2008 to 2017 were identified: failure to comply with the occupational safety requirements, incompetence of staff — 57 %; deterioration of health of an employee (due to hazardous working conditions at the company, with violations in the use of PPE and disregard to medical examinations) — 21 %; accidents at work (risk of injury taking into account the applied products and structures) — 22 %.

$$R\text{риск}=K\text{ут}\cdot R1+K\text{нд}\cdot R2+K\text{пс}\cdot R3, \qquad (2)$$

where $K\text{ут}=0.2$ — risk coefficient of working conditions;

$K\text{нд}=0.6$ — risk coefficient of incompetent actions;

$K\text{пс}=0.2$ — risk coefficient of accident at work;

$R1$ — occupational risk taking into account working conditions;

$R2$ — occupational risk taking into account an employee competence;

$R3$ — risk of an accident at work (disturbance of stability, breakage, unpredictable change in the internal state of potentially hazardous substances).

On the assessment scale of significance of risks the significance of risk is assessed (Table. 10), according to GOST R 12.0.010–2009. "Occupational safety standards system (SSBT). Occupational health and safety management systems".

Table 10

Risk values

Risk value interval	$0 < R \leq 5$	$5 < R \leq 10$	$10 < R \leq 15$
Risk importance	Low	Moderate	High

Hazard identification and risk assessment is carried out according to the Rrisk value.

Conclusion. An integrated method of occupational risk degree assessment is characterized by the simplicity of use, allows the safety engineer in the shortest possible time taking into account statistical data to make occupational risk assessment, thereby to reveal the most vulnerable links of production process. The disadvantage of this method is its absolute subjectivity.

In particular, statistics on industrial accidents is needed. To predict accidents at work associated with the violation of stability, breakdowns, unpredictable changes in the internal state of potentially hazardous substances, the safety engineer should take into account the operating conditions, the warranty period of work (MTBF), assess the state of technical devices of buildings and structures (taking into account their design features), restoration work. Next, it is necessary to identify accidents preconditions and consequences, make proposals to the head of the company on the creation of a system of protection from the accident and its localization.

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FACTORS AND CAUSES OF THE OCCURRENCE AND DEVELOPMENT OF ACCIDENTS AT OIL PRODUCTS SUPPLY FACILITIES

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The article analyzes the factors and causes of the occurrence and development of accidents at oil products supply facilities. It is shown that the main causes and factors of accidents are the presence of large amounts of oil and oil products at the facility, which are explosive and flammable substances, transportation of oil products under high pressure, operation of equipment under pressure at high temperatures, the presence of periodic processes and transient conditions of equipment as well as the corrosive activity of oil and oil products (especially with sulfur compounds).

Keywords: accident, oil and gas complex, explosion safety, industrial safety, risk analysis.

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ФАКТОРЫ И ПРИЧИНЫ ВОЗНИКНОВЕНИЯ И РАЗВИТИЯ АВАРИЙ НА ОБЪЕКТАХ НЕФТЕПРОДУКТООБЕСПЕЧЕНИЯ

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Анализируются факторы и причины возникновения и развития аварий на объектах нефтепродуктообеспечения. Доказано, что основными причинами и факторами возникновения аварий являются наличие на объекте большого количества нефти и нефтепродуктов, являющихся взрыво- и пожароопасными веществами, транспортирование нефтепродуктов под высоким давлением, эксплуатация оборудования под давлением при высоких температурах, наличие на объекте периодических процессов и переходных режимов работы оборудования, а также коррозионная активность нефти и нефтепродуктов (особенно при наличии сернистых соединений).

Ключевые слова: авария, нефтегазовый комплекс, взрывобезопасность, промышленная безопасность, анализ рисков.

Introduction. Oil-refining enterprises have a rather high level of threat of an emergency of natural and man-made character. Improving the safety of oil refining facilities is the main way to prevent threats of man-made nature, and therefore the factors and causes of accidents at oil products supply facilities during operation are among the most important tasks [1-2].

The existing problem can be solved by assessing the most common causes of accidents and eliminating factors that adversely affect the degree of industrial safety [3-4].

Main part. The causes of accidents and factors contributing to the occurrence and development of accidents at oil products supply facilities depend on the components of this facility.

Typical components of an oil product supply facility (e.g. an oil refinery) are:

- raw hydrocarbons processing facility;
- chemicals section;

- AT-400 facility;
- AT-400/2 facility;
- AT-5 facility;
- WT-1 facility.

For this technological equipment the characteristic factors, which can promote occurrence and development of accidents on objects of oil product supply will be:

1. the presence of oil products in the equipment, which are explosive-dangerous substances, as well as the presence of a constant source of ignition (furnace nozzles), which create a danger of fire, explosion due to emergency depressurization of the unit;
2. operation of equipment under pressure at high temperatures;
3. human factor: non-compliance with the technological equipment operation mode, errors in structure strength calculation;
4. failure of control and measuring equipment;
5. space-time factors;
6. presence of periodic processes and transient operation modes of equipment at the facility.

Possible causes of occurrence and development of accidents at oil product supply facilities for this process equipment will be:

1. parameters exceed critical values;
2. decrease in mechanical strength (defect in design);
3. corrosive wear of equipment;
4. depressurization of equipment as a result of loss of strength;
5. depressurization of equipment as a result of fire, leakage during depressurization of pipelines, adjacent equipment ("Domino effect»);
6. external impact of natural and man-made character;
7. unauthorized outside interference.

In addition to the considered process equipment and facilities at oil products facilities are located:

- feed and product department;
– tank battery;
- gas condensate loading station;
- facility for car loading and unloading of oil and oil products.

For these oil-refining facilities, the factors contributing to the occurrence and development of accidents will be:

1. the presence of significant amounts of gasoline as well as oil, diesel fuel, kerosene, marine low-viscosity fuel and fuel oil in tanks, which is a flammable liquid, which create the danger of the release of a large number of explosive substances during emergency depressurization of tanks and vessels;
2. large single volumes of tanks and main pipelines, which even with minor depressurization (or destruction) contribute to the release of a large number of hazardous substances;
3. availability of equipment of various types (pumps, pipelines, valves) with a significant number of welded and flange connections, valves and control valves;
4. the presence of sulfur compounds in oil and petroleum products, which contributes to the formation of pyrophoric compounds (in interaction with corrosion products), which in turn leads to the danger of their ignition with subsequent explosion or fire inside the equipment;
5. a wide range of hazardous secondary combustion products formed due to the complex fractional composition of petroleum products: nitrogen dioxide, carbon, sulfur dioxide, carbon monoxide, organic acids, carbon dioxide.

As a result of these factors, the possible causes of accidents at oil products facilities will be:

1. defects in the manufacture, installation and repair of equipment that can lead to full or partial depressurization;
2. failure of pipelines, fittings, separable joints, depressurization of the equipment due to internal mechanical defects, overload, mechanical damage, corrosion, and untimely removal of paraffin deposits;
3. influence of external factors (mechanical damage during loading and unloading, heating, atmospheric corrosion, etc.) on the equipment;
4. personnel errors during the technological process of oil/oil products transfer;
5. overpressure above the regulated values;
6. depressurization (destruction) of tanks at their overflow;
7. destruction or significant depressurization of tanks due to the formation of local areas of explosive mixtures of flammable liquids vapors with air at violations of technological regulations at repair works;
8. impact of fires and/or explosions on process equipment and pipelines;
9. errors of maintenance personnel.

Thus, the most significant factors affecting risk indicators at the oil product supply facilities are:

- availability of a large amount of oil and oil products that are explosive and fire hazardous substances at the oil product supply facility;
- transportation of oil products under high pressure;
- operation of equipment under pressure at high temperatures;
- availability of periodic processes and transient modes of equipment operation at the facility;
- oil and oil products corrosion activity (especially in the presence of sulfur compounds);
- pyrophoric compounds in oil.

The main measures that can be aimed at reducing the risk of accidents at oil products supply facilities are:

1. compliance with technological norms and safety parameters specified in technological regulations for the operation of technological equipment;
2. compliance by working personnel with the requirements, rules and norms of labor protection, fire and industrial safety when working with flammable and combustible liquids, training on labor protection;
3. carrying out periodic knowledge assessment of requirements of labor protection and industrial safety before the permit to unsupervised work;
4. timely technical examination of process equipment, devices and pipelines;
5. continuous pressure examination of process equipment and pipelines;
6. maintenance of fire hydrants, leakage detection systems and other safety equipment in working condition;
7. periodic examinations and individual testing of shut-off valves;
8. periodic ground checks of equipment and utilities in accordance with the operating Safety Rules for Operation of Consumer Electrical Installations;
9. periodic function tests of local communication flow chart of workers and engineers and technicians of the object (according to the approved schedule);
10. timely development of priority and future timed action plan (in the case of breaches) approved by the Federal Service for Environmental, Technological and Nuclear Oversight of Russia, for bringing industrial equipment into compliance with the norms and rules of safe operation;
11. timely replacement of worn-out and obsolete equipment;
12. strengthening measures to protect a hazardous production facility from possible terrorist acts;
13. improvement of professional skills of service personnel and its regular recertification;

14. training sessions and training alerts on the emergency response plan according to the approved schedules.

Conclusion. The conducted research allows to conclude that the main causes and factors of accidents are the presence of a large amount of oil and oil products at the facility, which are explosive and fire hazardous substances, transportation of oil products under high pressure, operation of equipment under pressure at high temperatures, presence of periodic processes and transient modes of operation of equipment, as well as the corrosion activity of oil and oil products (especially in the presence of sulfur compounds).

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THE RESULTS OF THE ANALYSIS OF THE SITUATION WITH FIRES IN THE REPUBLIC OF CRIMEA AND SEVASTOPOL

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The article describes the main indicators of the situation with fires in the Republic of Crimea and Sevastopol.

Their comparative analysis with values of indicators of a situation with fires across Russia and the southern Federal district is carried out.

It is shown that the average number of fires (per 1,000 people) in the Republic of Crimea and Sevastopol is less than in the southern Federal district and the Russian Federation as a whole in 2017. On the basis of the conducted research the directions of increase of combat readiness to performance of tasks on purpose of divisions of fire protection of the Crimean Peninsula are defined.

Keywords: the situation with fires, dead, injured, material damage, Crimea, Sevastopol.

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РЕЗУЛЬТАТЫ АНАЛИЗА ОБСТАНОВКИ С ПОЖАРАМИ НА ТЕРРИТОРИИ РЕСПУБЛИКИ КРЫМ И Г. СЕВАСТОПОЛЯ

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Рассмотрены основные показатели обстановки с пожарами на территории Республики Крым и г. Севастополя. Проведен их сравнительный анализ со значениями показателей обстановки с пожарами по России и Южному Федеральному округу.

Показано, что среднее количество пожаров (в расчете на 1 тыс. чел. населения) на территории Республики Крым и в г. Севастополь меньше, чем на территории Южного федерального округа и в Российской Федерации за 2017 год. На основе проведенного исследования определены направления повышения боеготовности к выполнению задач по предназначению подразделений пожарной охраны Крымского полуострова.

Ключевые слова: обстановка с пожарами, погибшие, травмированные, материальный ущерб, Крым, Севастополь.

Introduction. A sufficient number of statistical, analytical and other materials confirm that the Crimean Peninsula territory is exposed to a wide range of natural, man-made and biological and social hazards that pose a threat of emergency situations. Their study and systematization became the basis for assessing the risks of emergencies and fires, ranking the Peninsula by types of threats and optimizing measures to protect the population and territories taking into account the specifics of the Crimean Peninsula [1].

Problem statement. To analyze the situation with fires in the Republic of Crimea and Sevastopol, we used data on the number of fires, the dead and injured people in fires, direct material damage from fires from 2014 to 2017 in the subjects of the Russian Federation on the basis of statistical information from the Federal Data Banks (hereinafter — FDB) of FGBU VNIIPO of EMERCOM of Russia. Population indicators of the subjects of the Russian Federation are formed based on the data published by the State Committee of the Russian Federation on Statistics [4].

Theoretical part. Representative statistical data sets are used, as a rule, in the study of fire danger to the country, region, and settlements. Relative estimates are used for comparative evaluation of fire safety of regions. To do this, it is necessary to assess the probability of fire and assess the probability that the action of fire damaging factors will lead to human health damage (death or injury) [5-14].

One of the basic indicators necessary for the calculation of fire risk assessment is the frequency of fire during the year per one object or per one person (worker, student, visitor, etc.). Other relative indicators of the situation with fires are calculated the same way.

Table 1 shows the initial statistical data for the analysis of the situation with fires in the Republic of Crimea and Sevastopol of the Southern Federal District of the Russian Federation for 2017.

Table 1

Statistical data for the analysis of the situation with fires in the Republic of Crimea and Sevastopol of the Southern Federal District of the Russian Federation for 2017

Geographical administrative division	Population, thousand people	Number of fires, unit	Number of catching fires, unit	Number of fatalities in fires, victim	Number of injured people in fires, victim	Direct material damage, thousand rub.
Sevastopol	436.7	267	1470	8	20	17243
Republic of Crimea	1913.7	989	5667	65	76	63850
Southern Federal District	16441.8	11543	50964	724	986	749214
Russian Federation	146880	132844	314229	7816	9355	13767378

As all the indicators of fire situation have strong positive dependence on population, for the analysis and comparison of indicators of fire situation in the Republic of Crimea and Sevastopol with all-Russian, we used relative indicators of fire situation per one thousand people of the population (Table 2) and per one fire (Table 3).

Table 2

Relative indicators of fire situation in the Republic of Crimea and Sevastopol of the Southern Federal District of the Russian Federation for 2017 on average per 1 thousand people.

Geographical administrative division	Population, thousand people	Average number of fires, unit/thousand people	Average number of catching fires, unit/thousand people	Average number of fatalities in fires, victim/thousand people	Average number of injured people in fires, victim/thousand people	Average direct material damage, rub./person
Sevastopol	436.7	0.61	3.37	0.018	0.046	39.48
Republic of Crimea	1913.7	0.52	2.96	0.034	0.040	33.36
Southern Federal District	16442	0.70	3.10	0.044	0.060	45.57
Russian Federation	146880	0.90	2.14	0.053	0.064	93.73

Table 3

Relative indicators of fire situation in the Republic of Crimea and Sevastopol of the Southern Federal District of the Russian Federation for 2017 on average per 1 fire

Geographical administrative division	Population, thousand people.	Number of fires, unit	Number of catching fires, unit	Average number of fatalities in fires, victim/fire	Average number of injured people in fires, victim/fire	Average direct material damage, thousand rub./fire
Sevastopol	436.7	267	1470	0.030	0.075	64.58
Republic of Crimea	1913.7	989	5667	0.066	0.077	64.56
Southern Federal District	16442	11543	50964	0.063	0.085	64.91
Russian Federation	146880	132844	314229	0.059	0.070	103.64

Table 2 shows that the average number of fires (per 1,000 people) in the Republic of Crimea and Sevastopol is less than in the Southern Federal District and in the Russian Federation in 2017. It is necessary to pay attention to the greater value of the "average number of fires" indicator in the Republic of Crimea and Sevastopol in comparison with the all-Russian values for 2017. This fact may indicate a greater number of factors causing fire danger in the Republic of Crimea and Sevastopol, and the increased readiness of fire and rescue divisions of the Republic of Crimea and Sevastopol, which in time found the most number of fire outbreaks and managed to localize them, without bringing them to big fires.

It should be noted that the average number of people injured in fire in the Republic of Crimea and Sevastopol is higher than the all-Russian values for 2017, but do not exceed similar indicators for the Southern Federal District (Fig. 1).

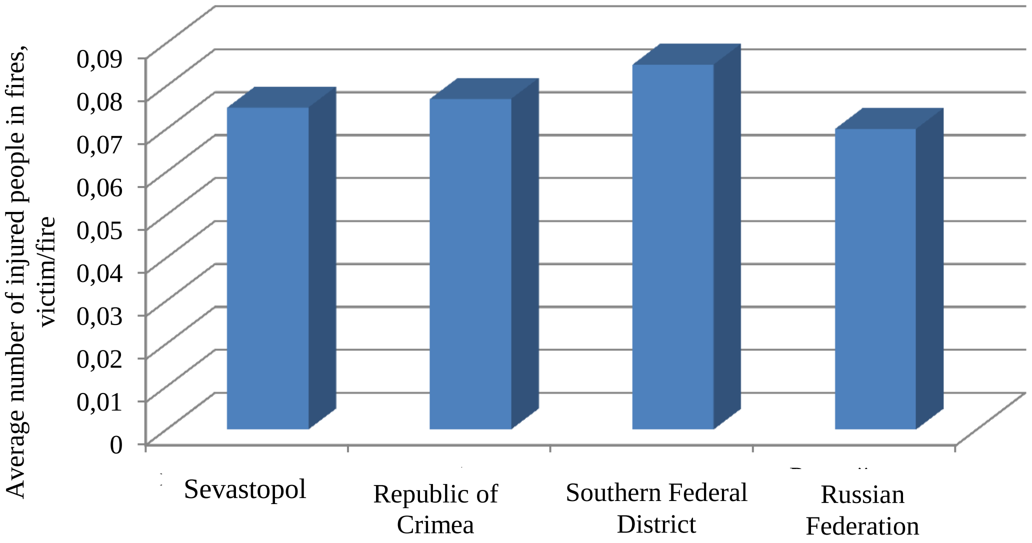

Fig. 1. Comparison of the average number of people injured in fires per 1 fire in the Republic of Crimea, Sevastopol, the Southern Federal District and the Russian Federation for 2017

Fig. 2-5 show the dynamics of relative indicators of fire situation from 2014 to 2017 per 1 thousand people (for fires) and per fire 1 (the death and injury of people in fires). It is necessary to pay attention to the increase in the number of fires per 1 thousand people in the Republic of Crimea and the excess of this indicator in Sevastopol over the all-Russian values. Also noteworthy is the growth in the average number of injured people in fires that occurred in the Republic of Crimea in 2014-2017, per 1 fire.

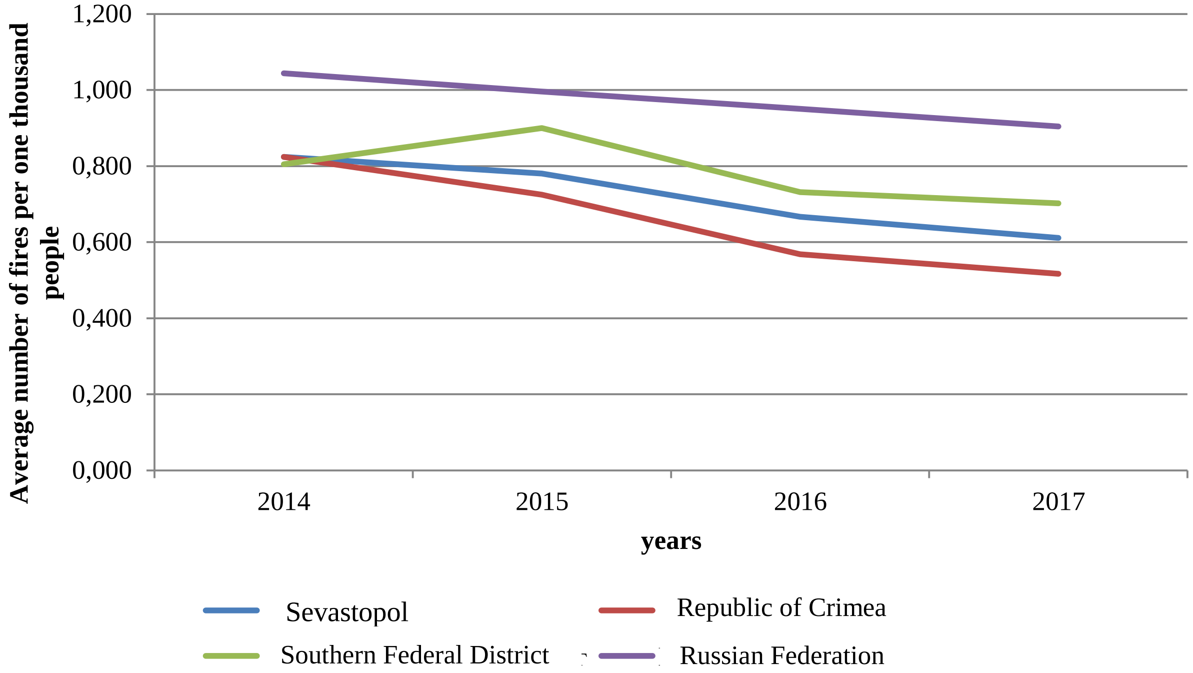

Fig. 2. Dynamics of changes in the average number of fires that occurred in the Republic of Crimea, Sevastopol, Southern Federal District and the Russian Federation in 2014-2017

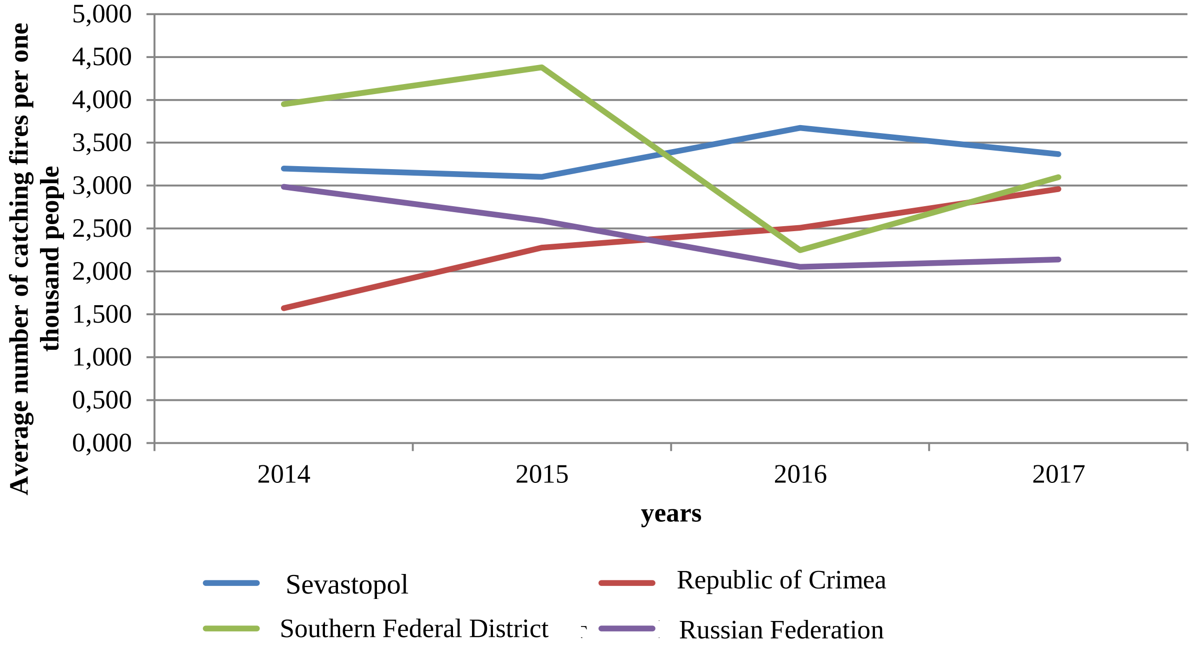

Fig. 3. Dynamics of changes in the average number of catching fires that occurred in the Republic of Crimea, Sevastopol, the Southern Federal District and the Russian Federation in 2014-2017

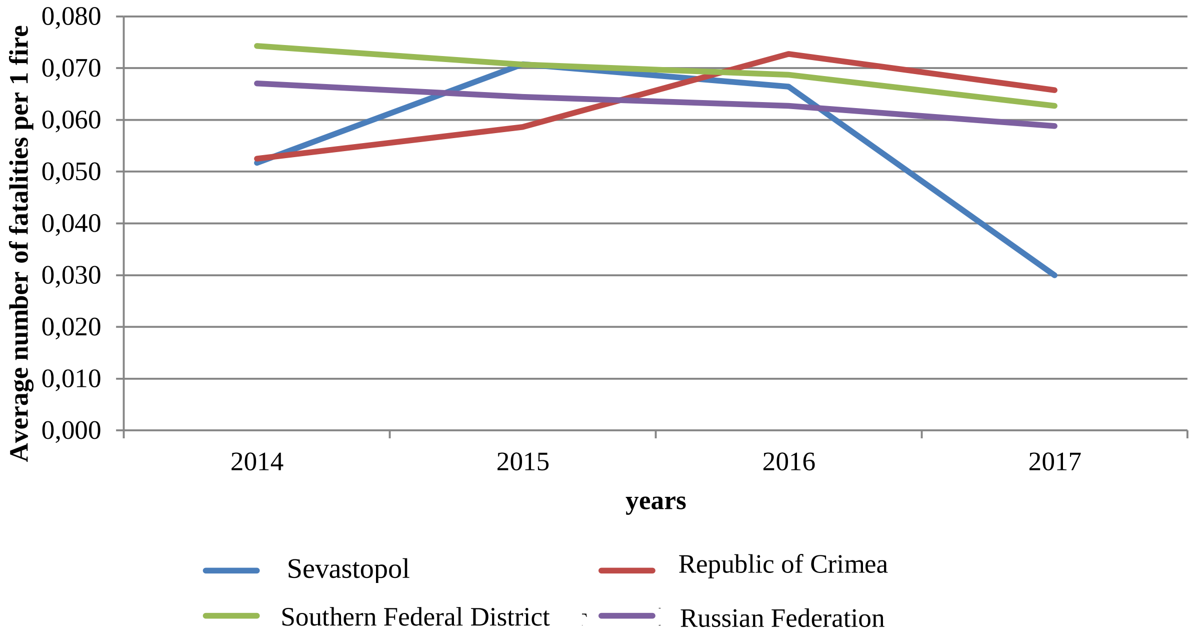

Fig. 4. Dynamics of changes in the average number of fatalities in fires that occurred in the Republic of Crimea, Sevastopol, the Southern Federal District and the Russian Federation in 2014-2017, per 1 fire

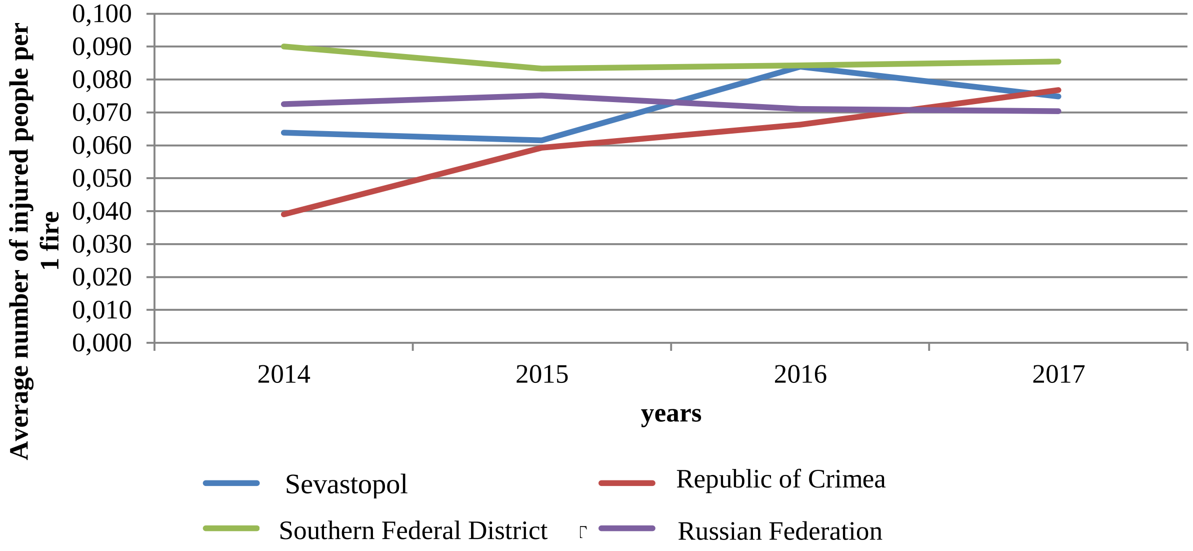

Fig. 5. Dynamics of changes in the average number of injured people in fires that occurred in the Republic of Crimea, Sevastopol, the Southern Federal District and the Russian Federation in 2014-2017, per 1 fire

Conclusion. Based on the analysis of the fires situation indicators state, it can be concluded that the fire and rescue departments of the Republic of Crimea, Sevastopol are ready to solve the problems of fire safety. Directions for possible increase of readiness of fire and rescue departments of the Republic of Crimea and Sevastopol for the solution of tasks of ensuring fire safety — decrease in the number of fires in the controlled territory and decrease in the level of traumatism at fires are determined.

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ANALYSIS OF ACCIDENTS AND INJURIES AT EXPLOSIVE OBJECTS OF STORAGE AND PROCESSING OF PLANT RAW MATERIALS

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The purpose of the analysis is to determine the complete picture of accidents and injuries of personnel with fatal consequences at explosive storage and processing of plant raw materials. The analysis is aimed at comparing data on the types and causes of accidents, as well as comparing data on fatal accidents, taking into account the risk and prevalence of traumatic factors. Along the way, the analysis of the impact of Supervisory activities on the safety of hazardous production facilities engaged in the storage and processing of plant raw materials was carried out. A comparison of the number of hazardous production facilities in different periods of time and the number of accidents and accidents occurred.

Keywords: Accident, accident, incident, explosion, human factor, fire, dust mixture, destruction of facilities, industrial safety, labor protection.

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АНАЛИЗ АВАРИЙНОСТИ И ТРАВМАТИЗМА НА ВЗРЫВОПОЖАРООПАСНЫХ ОБЪЕКТАХ ХРАНЕНИЯ И ПЕРЕРАБОТКИ РАСТИТЕЛЬНОГО СЫРЬЯ

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Целью работы являлось представление целостной картины аварийности и травматизма персонала со смертельным исходом на взрывопожароопасных объектах хранения и переработки растительного сырья. Сопоставлены данные по видам и причинам аварий. Проведен анализ влияния надзорной деятельности на безопасность опасных производственных объектов, осуществляющих деятельность по хранению и переработке растительного сырья. Проведено сопоставление количества опасных производственных объектов в различные периоды времени и количества произошедших аварий и несчастных случаев.

Ключевые слова: авария, несчастный случай, инцидент, взрыв, человеческий фактор, пожар, пылевоздушная смесь, разрушение сооружений, промышленная безопасность, охрана труда.

Introduction. Fire explosive storage facilities for processing plant raw materials are classified as hazardous production facilities of III and IV hazard class [1]. Great attention is drawn to the problems of fatal personnel accidents and injuries at such facilities. The occurrence of accidents at these facilities leads to significant destruction, fatalities and, which is important, to huge financial losses. The analysis of emergencies and accidents is aimed at evaluating the overall status of accidents, identification of causes, and determination of ways to reduce the impact of accidents and to reduce the number of accidents. According to the analysis of the data from the annual reports on the activities of the Federal Service for Environmental, Technological and Nuclear Supervision from 2013 to 2017 on fire explosive facilities for storage and processing of plant raw materials, it follows that during the reporting period there were 6 accidents and 21 fatal accidents [2]. In 2017, 2 accidents and 5 fatal accidents occurred at fire explosive facilities for storage and processing of plant raw materials in the Russian Federation.

Main part. Over the past five years, the number of supervised organizations and operated fire explosive facilities for storage and processing of plant raw materials has decreased. The number of supervised organizations decreased by 2.78 %, while the number of operated hazardous production facilities decreased by 15.2 %. In absolute terms, the number of supervised objects decreased by 1609 units. Despite the current trend of reduction of operated hazardous production facilities for storage and processing of plant raw materials, the annual quantitative indicators of accidents at the above facilities do not decrease over time (Fig. 1). Similar statistics is in the earlier period. Thus, according to the analysis of statistics (Fig. 2), we observe a similar pattern of accidents [3].

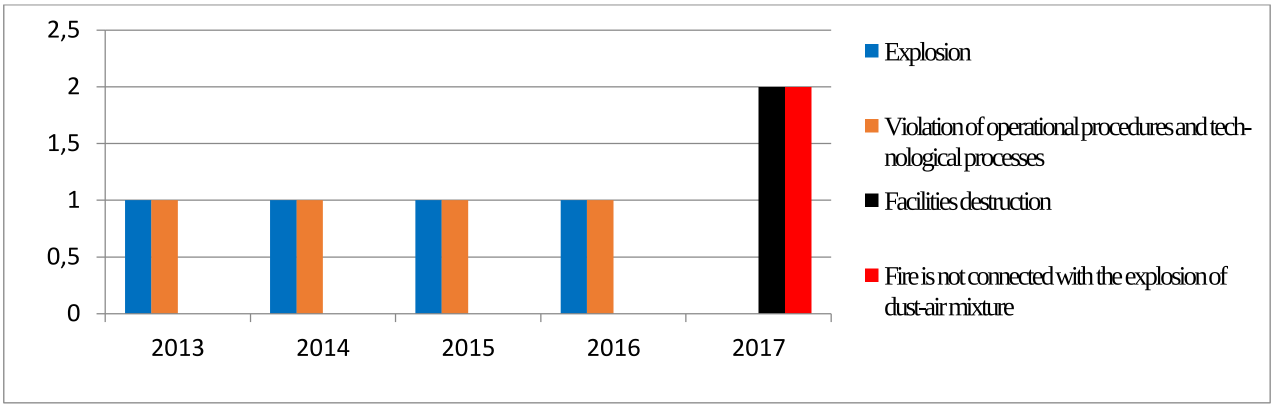

Fig. 1. Distribution of accidents by types and causes from 2013 to 2017

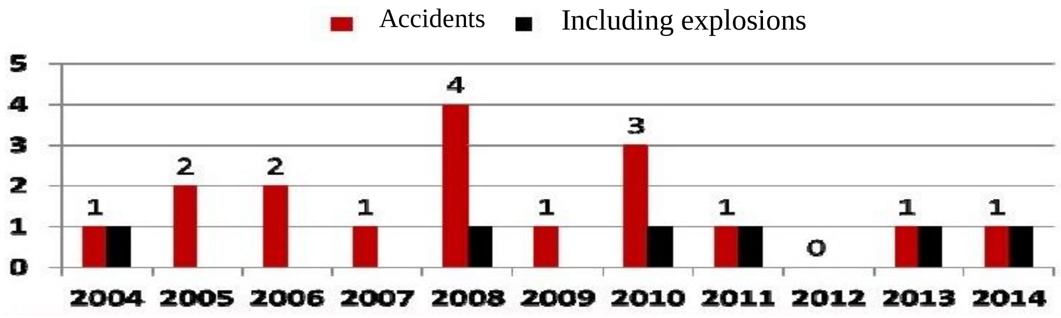

Fig. 2. Total number of accidents at hazardous production facilities for storage and processing of plant raw materials from 2004 to 2014

The most vulnerable in the context of explosion safety are elevators, feed and flour mills, and, with a small lag, silo warehouses [4]. It should be noted that the accidents mentioned in the statistics above are approximately equally distributed between hazard class III and hazard class IV.

The number of fatal accidents at fire explosive facilities for storage and processing of plant raw materials does not decrease during the analyzed period from 2013 to 2017. (Fig. 3). In just 5 years, there have been more than 20 fatal accidents. It should be noted that 70% of fatal accidents occurred at hazardous production facilities of hazard class III and only 30% at facilities of hazard class IV. Gradation of traumatic factors by the number of accidents occurred over the past 5 years is as follows (Fig. 4).

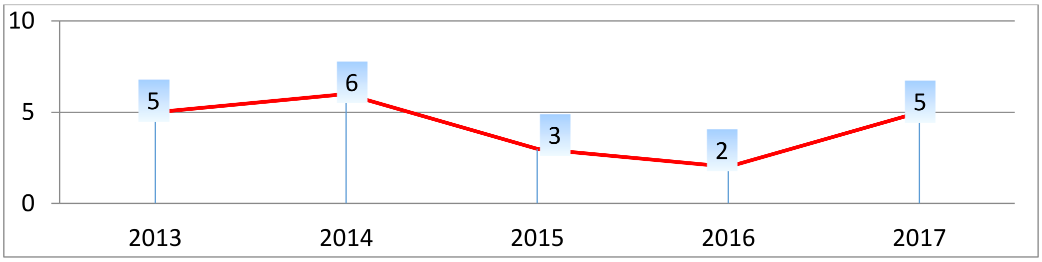

Fig. 3. Dynamics of the number of the occurred fatal accidents

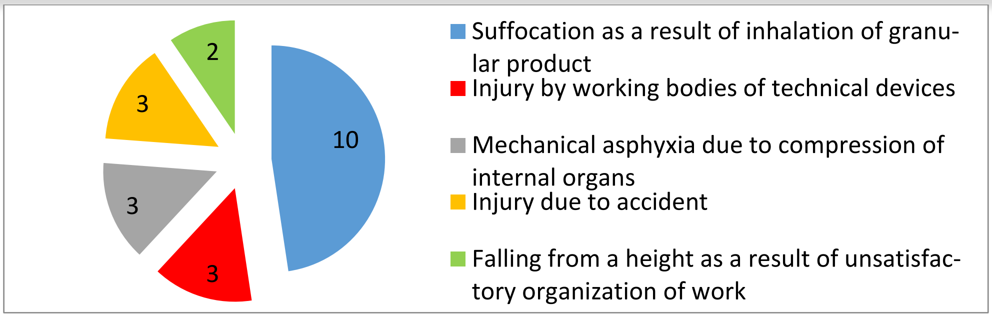

Fig. 4. Gradation of traumatic factors

The total number of incidents that occurred at the fire explosive facilities for storage and processing of plant raw materials is rapidly decreasing over the past five years (Fig. 5). It should be borne in mind that the picture may not be entirely objective due to incomplete information submitted to the bodies of Rostekhnadzor by operating organizations.

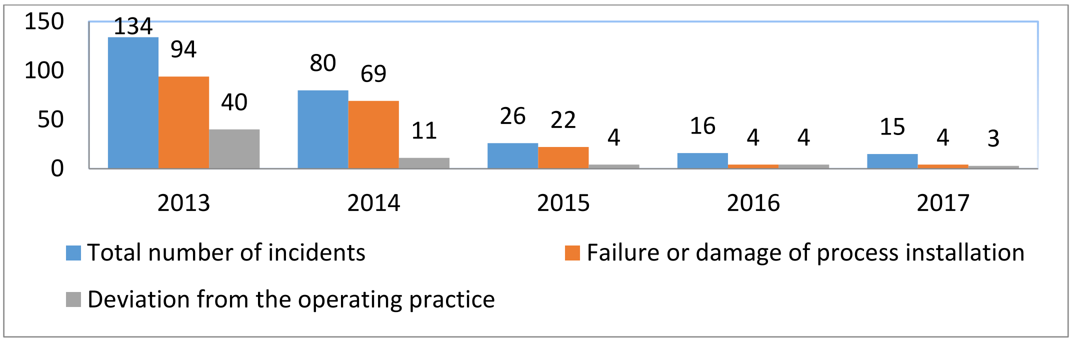

Fig. 5. Number and nature of incidents from 2013 to 2017

The analysis of supervisory activities for the same period from 2013 to 2017 shows that the total number of inspections has decreased sharply by almost 3.4 times. The number of scheduled inspections decreased by 5 times, and the number of unscheduled inspections decreased by 2.3 times. As expected, the total number of detected violations also decreased during the analyzed period. Thus, the total number of detected violations decreased from 2013 to 2017 by 2.3 times (by 57%). Quantitative indicators of measures taken to owners of hazardous production facilities in the detection of violations of industrial safety requirements, respectively, are reduced. However, as practice shows, with a decrease in the number of inspections, detected violations and applied measures, the number of emergencies and accidents remains at the same level. At the same time, the administrative burden on the supervised organizations and, first of all, on the regulatory authorities is reduced. The available administrative resources can be directed to the control of hazardous production facilities of higher hazard class.

Conclusion. The main causes of emergencies, incidents and accidents, largely, are violations of the order of work, processes, health and safety requirements. Production control is not provided properly, which is an indicator of the influence of human factor on the emerging problems [5]. Thus, three factors of occupational safety [6] remain without attention: human, industrial and organizational. In production, there is a certain problem between the high level of modern technology and the low level of its operation and maintenance. This is also true for complex processes. These findings are prerequisites to the consideration of further ways of safety provision at fire explosive facilities for storage and processing of plant raw materials using digital technologies in the context of a risk-based approach. The application of this approach should lead to a reduction in the burden not only on the supervised organizations, but also on the supervisory authorities themselves, thereby increasing the transparency and quality of organization of production control within enterprises.

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ANALYSIS AND MODELING OF A DYNAMIC INTERACTION BETWEEN THE COMBINED POPULATIONS

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The analysis of the combined populations of «predator–victim». Based on the discrete data of the growth of the population by years determined a rough plan of the regulation of population size. The cases of the location of the two predators in the area.

Keywords: the population size, modelling, discrete analysis

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АНАЛИЗ И МОДЕЛИРОВАНИЕ ДИНАМИКИ ВЗАИМОДЕЙСТВИЯ ОБЪЕДИНЁННОЙ ПОПУЛЯЦИИ

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Проведён анализ объединённой популяции «хищник-жертва». На основе дискретных данных прироста численности популяции по годам определён примерный план регуляции численности популяции. Рассмотрены случаи нахождения двух хищников на ареале.

Ключевые слова: численность популяции, моделирование, дискретный анализ.

Introduction. Environmental crisis currently developing on our planet is global and covers the entire biosphere. Its structure includes, among other things, the natural component, which is expressed in the visible degradation of the environment, the destruction of living organisms because of changes arising in it under the influence of human activity [1-3]. The extinction of biological species is dangerous for the biosphere because it leads to a decrease in biological diversity of natural ecosystems, which ensures their resistance to various external influences [1, 2].

Problem statement. "Predator-prey" interaction is one of the most widespread types of biotic interactions in nature. Predation is when animals (predators) find, grab, kill and eat other animals (preys) while getting food. Predators often catch and kill sick or non-viable individuals of prey, as a rule, not involved in reproduction, so predators can be attributed to the effective "methods" of evolution of living organisms [1-3]. Based on the above, it is obvious that studies on forecasting the number of natural populations, depending on a certain type of impact, are currently relevant.

Theoretical models of combined populations. In the course of evolutionary development, which is based on the interaction between predator and prey, the soundest and most adapted to the influence of environmental factors individuals survive in the population. That is, "predator-prey" is an interaction, in the process of which representatives of predators and representatives of preys evolve [1, 2].

In natural conditions, there is the following time and cause-and-effect chain: prey reproduction - predator reproduction - sharp reduction of prey number - reduction of predator number –prey reproduction, etc. [4, 5]. This cybernetic system with negative feedback leads to a stable equilibrium. Waves of fluctuations of predator and prey follow each other with constant phase difference, and on the average, the number of both predator, and prey remains constant [4].’

The model of coexistence of biological species on the type of "predator-prey" is called Lotka–Volterra model. This model was first used by Alfred Lotka in 1925 to describe the dynamics of interacting biological populations. In 1926-1931, similar and more complex models were developed by Italian mathematician Vito Volterra, who derived the laws of periodic cycle, conservation and violation of averages in the study of the relationship between predator and prey [1, 4, 6].

In case of existence of any interspecies interaction, including the "predator-prey" type, the population is called "combined". Systems of homogeneous differential equations of first order, represented in Fig.1 are used in the description of such interspecies interactions

$$\begin{cases} \dfrac{dN_1}{dt} = \overbrace{a_1 N_1}^{\text{I}} + \overbrace{b_{12} N_1 N_2}^{\text{II}} \overbrace{- c_1 N_1^2}^{\text{III}} \\ \dfrac{dN_2}{dt} = \underbrace{a_2 N_2} + \underbrace{b_{21} N_1 N_2} \underbrace{- c_2 N_2^2} \end{cases}$$

Fig.1. General scheme of differential model components of combined population

In these systems: N_1 and N_2 — number of predator and prey populations; a_1 and a_2 —population growth rate coefficients; b_{12} and b_{21} —population interaction coefficients; c_1 and c_2 —coefficients of population self-limitation (intraspecific competition, anthropogenic impact, natural mortality).

The equations of population dynamics speed are divided into three sections (Fig. 1) [7, 8]:

I — section of own exponential growth: components for describing population dynamics without limiting factors;

II — section of interspecies interaction: the form of interspecies interaction is determined by the sign of coefficients b_{12} and b_{21}, and the degree of interaction is determined by their value;

III — section of limiting factors: natural mortality, intraspecific competition, anthropogenic impact.

In the form of predator-prey interaction, the coefficients in section II have different signs, i.e. the predator is the limiting factor for the prey and the prey is the food resource for the predator.

Anthropogenic impact of human hunting for predators is introduced in section III as a separate component and acts as a limiting factor [2, 9].

Selection of initial conditions and calculation results. Deer was chosen in this work as a prey in the model "predator-prey". In Russia deer is found in the Northern European parts, in the Far East, Northern Urals, in forests and tundra of Western and Eastern Siberia.

The largest reduction in the number of reindeers contributes to the population of their natural enemies — predators. Depending on the habitat of species of living organisms, the impact of predators on reindeer populations is quite different. This may be due to the number of populations of both predators and preys, the presence or absence of other types of food, as well as the number of other environmental conditions of living organisms, including climatic features of the territory [5, 10, 11].

It is the wolf, as a predator, that is the main natural enemy of reindeer in nature. The largest number of individuals of reindeer populations suffers from wolf attacks on the vast territories of tundra and forest-tundra. The populations of wolves move behind the populations of reindeer, so the habitats and the number of wolf populations are directly dependent on the quantitative characteristics and migration of reindeer populations [1, 5].

Lynx is the northernmost species of cat family. The diet of lynx includes both medium and large ungulates, including deer [1, 2].

In this paper, we consider the relationship between the predators represented by wolves and lynx, and the prey - deer, with the following initial data:

— the number of individuals of prey population (deer) - no more than 1828, each year the population increases by 0.387 units;

— the number of individuals of main predators population (wolves) — no more than 15, there are 33 deer per wolf per year, wolf population increases by 0.126 units each year;

— the number of individuals of additional predators population (lynx) is unknown, one lynx per year accounts for 21 deer, each year the population of lynxes increases by 0.218 units;

— death of individuals of prey population (deer) is only due to interspecific interactions with predators populations (wolves and lynx) and for no other reasons;

— death of individuals of predator populations (wolves and lynx) does not occur at all.

To analyze the size of the combined population, the following problems were set in a discrete form:

Problem 1: calculate the number of deer individuals in one and three years and in five and ten years in the absence of interspecies interactions with predators;

Problem 2: calculate the number of individuals in deer population at the same time intervals, if the number of individuals in wolf population is 15 and does not change during the specified time intervals;

Problem 3: calculate the number of individuals in deer population at the same time intervals, if the number of individuals of wolves is 15 and increases each year by a given proportion;

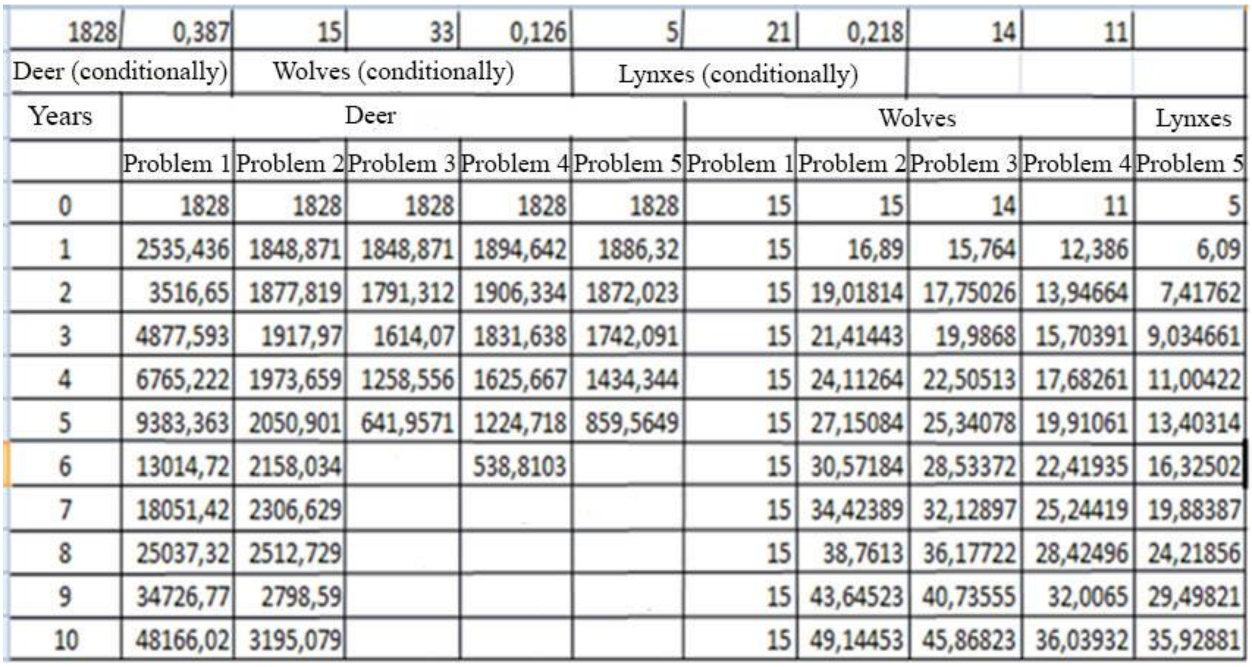
Problem 4: calculate the number of individuals of increasing wolf population in which the number of individuals of deer will remain approximately the same (about 2 thousand) during the initial five years of life of the population;

Problem 5: calculate the initial number of individuals of wolf and lynx populations, in which the number of individuals of deer population will remain approximately the same (about 2 thousand) during the initial five years of life of the population.

The calculations were performed in Microsoft Excel. The results of the calculations are presented in Table 1.

Table1

Calculation results of the combined population in a discrete form



1828	0,387	15	33	0,126	5	21	0,218	14	11	
Deer (conditionally)		Wolves (conditionally)			Lynxes (conditionally)					
Years	Deer					Wolves				Lynxes
	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5
0	1828	1828	1828	1828	1828	15	15	14	11	5
1	2535,436	1848,871	1848,871	1894,642	1886,32	15	16,89	15,764	12,386	6,09
2	3516,65	1877,819	1791,312	1906,334	1872,023	15	19,01814	17,75026	13,94664	7,41762
3	4877,593	1917,97	1614,07	1831,638	1742,091	15	21,41443	19,9868	15,70391	9,034661
4	6765,222	1973,659	1258,556	1625,667	1434,344	15	24,11264	22,50513	17,68261	11,00422
5	9383,363	2050,901	641,9571	1224,718	859,5649	15	27,15084	25,34078	19,91061	13,40314
6	13014,72	2158,034		538,8103		15	30,57184	28,53372	22,41935	16,32502
7	18051,42	2306,629				15	34,42389	32,12897	25,24419	19,88387
8	25037,32	2512,729				15	38,7613	36,17722	28,42496	24,21856
9	34726,77	2798,59				15	43,64523	40,73555	32,0065	29,49821
10	48166,02	3195,079				15	49,14453	45,86823	36,03932	35,92881

Conclusion. The results of the calculations carried out under the given conditions showed that during the first five years the number of individuals of prey population (deer) will remain stable in all five problems. Thus, in the course of work the possibility of forming the balance of the combined population "predator-prey" on the basis of the discrete data calculation in the regulation of the initial population of the predator was justified. For a detailed study of the model, it is necessary to conduct a differential analysis of the phase portrait of the combined population.

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